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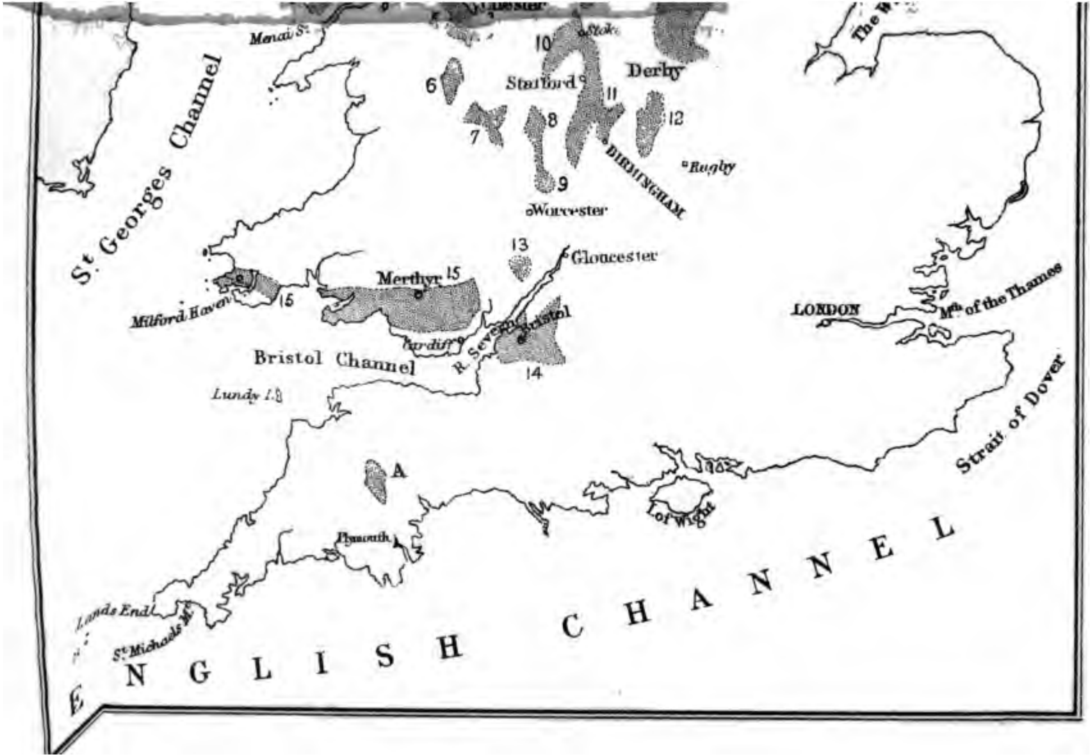
PRINCIPLES OF COAL MINING.


OUTLINE MAP
OF THE
BRITISH COAL FIELDS.
Mull
Iona
Colonsay
Jura
Islay
Dundee
R. Tay
Firth of Forth
GLASGOW
EDINBURGH
21
20
20
22
19
23
18
1
Newcastle
Carlisle
R. Tees
Belfast
Solway Firth
17
I. of Man
Leeds
Bradford
York
Hull
IRISH SEA
Preston
4


Menai St.
St. Georges Channel
6
7
8
9
10
11
12
13
14
15
Stafford
Stoke
Derby
Birmingham
Rugby
Worcester
Gloucester
Merthyr
Milford Haven
Cardiff
R. Severn
Bristol
Bristol Channel
Lundy I.
A
Plymouth
Lands End
St. Michaels Mt.
I. of Wight
London
Mth. of the Thames
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PRINCIPLES

OF

COAL MINING

BY

J. H. COLLINS, F.G.S.,

AUTHOR OF A "HANDBOOK TO THE MINERALOGY OF CORNWALL AND DEVON."
"A FIRST BOOK OF MINERALOGY," "PRINCIPLES OF METAL MINING," ETC.
HONORARY SECRETARY TO THE MINER'S ASSOCIATION OF CORNWALL AND DEVON.

With 139 Illustrations.

NEW YORK
G. P. PUTNAM'S SONS
FOURTH AVENUE AND TWENTY-THIRD STREET.

PREFACE

In preparing this work I have supplemented my own observations in the colliery districts of Staffordshire, Somersetshire, and South Wales, by making free use of the information contained in Mr. W. W. Smyth's excellent *Coal and Coal Mining*, Mr. Greenwood's *Mine Engineering*, and Professor Hull's *Coal-fields of Great Britain and Ireland*. To these authors, and to various writers in the "Proceedings of the South Wales Institute of Engineers," those of the "Institution of Mechanical Engineers," and some others, as well as to sundry friends, for information privately supplied, I hereby acknowledge my indebtedness, and offer to them the thanks to which they are fully entitled.

The unusually large number of illustrations will render the book useful to the youngest students of mining, for whom the book is primarily intended. Should more advanced students notice any errors or omissions, important or unimportant, I shall be glad to be apprised of them.

J. H. C.

Truro, *November, 1875.*

CONTENTS.

PRINCIPLES OF COAL MINING.

CHAPTER I.

INTRODUCTION.

1. Coal Mining, the youngest and at the same time the most important branch of the mining art, at least so far as the United Kingdom is concerned, differs from metal mining, and especially from vein-mining, in many important particulars; and it is the object of this treatise to aid the young coal miner in his daily labours, by putting before him the results of experience in many different localities.

2. Annual Production.—The importance of this branch of mining is well shown in Mr. Hunt's official returns of coal and ore production in the United Kingdom, from which it appears that in 1873 no fewer then 127 millions of tons of coal were raised, of an estimated value of £47,631,280, or an average of nearly 7s. 6d. per ton at the pit's mouth. During the same period the metallic ores produced amounted to less than 17 millions of tons, of an estimated average value as sold of £10,288,413, or about 12s. 10d. per ton.

3. Comparative Bulk.—This difference in the value of the minerals appears more striking if we compare the relative *bulk* of the materials for equal weights or values. Taking the coal to weigh about one ton for each cubic yard, which is pretty near the truth, the ores will, on an

average, be at least twice as heavy; in other words, while a cubic yard of coal is worth only 7s. 6d., a cubic yard of ore will be worth 25s. 8d. This fact alone necessitates a different mode of dealing with the material raised; in larger and straighter shafts, more perfect arrangements for underground transit and for hauling to surface; also in the leaving behind of a larger proportion of valuable material to support the roof instead of timber or other artificial support. Add to this, that the dimensions of the workable masses must be much greater than in metal mining, in order to yield a fair profit upon the capital invested; that there are special kinds of danger from sudden evolutions, or ancient accumulations of gas or water, and from falls of roof, to be guarded against; peculiar arrangements in aid of ventilation to be contrived, and extraordinary difficulties in sinking shafts in stratified rocks of varied texture to be overcome, and it will be quite evident that this branch of mining must be studied from its own proper standpoint.

4. **Number of Collieries.**—The magnitude of this industry is indicated by the fact that, in 1873, no fewer than 3559 collieries were reported as actually at work in the United Kingdom, according to the following table compiled from Hunt's *Mineral Statistics* for 1873:

Northumberland and North Durham,	184
Cumberland,	37
Westmoreland,	2
South Durham,	161
Yorkshire,	504
Derbyshire,	156
Nottinghamshire,	34
Warwickshire,	24
Leicestershire,	16
North Staffordshire,	123
South Staffordshire and Worcestershire,	407
North and East Lancashire,	325*
West Lancashire,	160
Cheshire,	31*
Shropshire,	60*
Gloucestershire,	92
Somersetshire,	34

Monmouthshire, - - - - - - -	91
East Glamorganshire, - - - - - -	22*
West and Central Glamorgan, - - -	347
Brecknockshire, - - - - - - -	6
Pembrokeshire, - - - - - - -	11
Carmarthenshire, - - - - - -	65
Flintshire, - - - - - - - -	62
Denbighshire, - - - - - - -	50
Anglesey, - - - - - - - -	3
Scotland, West Division, - - - - -	239
,, East Division, - - - - -	269
Ireland, Ulster coal-field, - - - - -	9
,, Connaught coal-field, - - - -	30
,, Leinster coal-field, - - - - -	40
,, Munster coal-field, - - - - -	26
	3620
Of these not working (Irish), - - -	61
Actually working, - - - - - -	3559

* These returns are not corrected for 1873. They should probably be higher.

CHAPTER II.

GENERAL DESCRIPTION OF COAL STRATA.

5. Mode of Occurrence.—Beds of coal occur interstratified with beds of sandstone, limestone, and other rocks, and some portions are occasionally met with in an

Fig. 1.

almost vertical position, as in fig. 1, highly inclined as in fig. 2, east, or horizontal as in fig. 2, west. For a full

account of the peculiar characteristics of the coal-bearing strata in the United Kingdom and in foreign countries the student must refer to works on geology, but the situation of known deposits of coal or other combustible

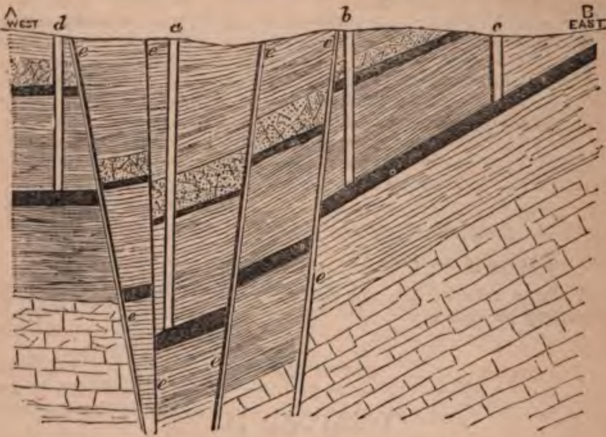

Fig. 2.

material is indicated in the following table of the chief "formations," divisions, or groups of stratified rocks which is taken from the volume on *Metal Mining.*

No.	Formation.	Chief Mineral Contents.
1.	**Post Tertiary.** —	Peat bogs of the United Kingdom. Stream tin of Cornwall in river gravels. Copper deposits of Lake Superior. Alluvial gold of Australia and California.
2.	**Pliocene**.............	**Surturbrand Lignite** of Iceland. Large deposits of bones and excrement of fishes (known as coprolites), obtained by a rude species of mining from Suffolk and Essex, and used for making artificial manures. Some of the "deep leads" of the Australian gold-fields.

3. **Miocene**............Some of the **lignites** or **brown coals** of Ireland are of this age. **Lignite** beds of Bovey Tracey in Devon, Antrim, Mull, Austrian Alps, Germany, and Vancouver's Island.

4. **Eocene**...............**Lignites** of Tyrol, Venetian Alps, and Southern Styria. Gypsum of Montmartre.

5. **Cretaceous**.........**Lignite** of Gosau, in the Austrian Alps; and of Santa Fe de Bogota, in S. America. **Coal** of Moravia. Iron ore beds of Sussex. Copper ores of Algiers and Chili.

6. **Oolitic & Liassic.**—**Coal** of Kimmeridge, Brora, Funfkirchen, and Steierdorf, in S. Hungary; Pennsylvania. **Brown Coal** of N. Germany. Copper deposits of the Banat, in Austria, and of Department l' Aveyron, in France. Iron ores of Cleveland and Rosedale, in Yorkshire.

7. **Triassic**.............**"Letterkohle"** of South Germany. **Coal** of Virginia, U.S., and of New South Wales (part). Copper of Chessy, in France. Lake Superior, Connecticut, New Jersey, and Pennsylvania.

8. **Permian**............**"Branschiefer"** of Germany and Bohemia. **Coal** of India and of New South Wales (part). Copper deposits of the west side of the Ural Mountains. Mansfield, in Prussia; Hesse, Thuringia. Rock salt of Worcestershire and Cheshire.

9. **Carboniferous**......**Coal measures** of Gt. Britain and Ireland, France, Belgium, Prussia, Bohemia, Moravia, Spain, United States, and Nova Scotia. **Anthracite** of South Wales, Ireland, and Pennsylvania. **Coal** of New South Wales (part). Lead mines of Derbyshire and Cumberland. Clay ironstone of the coal measures.

10. **Devonian**...........**Coal** of New South Wales (part). Tin, copper, iron, and lead lodes of Cornwall and Devon. Copper lodes of Wexford.

11. **Silurian**.............**Anthracite** of County Cavan, Ireland; of Isle of Man and Norway. **Graphite** of Cumberland. Copper of the east flank of the Urals. Lead of Isle of Man.

12. **Cambrian**...........

13. **Laurentian**.........**Graphite** beds of North America. Copper of Norway and Sweden.

6. Carboniferous System of Britain.—In Britain it is rare to meet with beds (*seams*) of coal of commercial value except in the carboniferous series of rocks. Our chief attention must therefore be here confined to these rocks. The carboniferous system, in general, consists of the following members, viz.—

1. **The Coal Measures.**—Strata of shale, sandstone, and grit, from 600 to 12,000 ft. thick, with occasional seams of coal.
2. **The Millstone Grit.**—A coarse sandstone, sometimes used for millstones, passing into conglomerate—beds of shale, and coal, in the North of England and Scotland—devoid of coal in South of England and South Wales, often 600 ft. thick.
3. **Carboniferous or Mountain Limestone.**—Thick limestone beds full of corals, encrinites, and other fossils, with beds of shale near the top and bottom, generally devoid of coal, except in Scotland; 200 to 1500 ft. thick.

7. Fossils.—Each of these sub-divisions are characterised by their own proper fossil remains, which are usually very abundant in the coal shales and limestone, but rare in the grit. Figs. 3, 4, 5, 6, 7, 8, 9, are characteristic fossils

Fig. 3.

Fig. 4.

Fig. 5.

in the carboniferous limestone; figs. 10 to 17 are characteristic of the coal measures.

Figs. 3 and 4 are corals; fig. 5 the fossil known as *Spirifera striatus;* fig. 6, *Productus giganteus*; and fig. 7, *Euomphalus pentangulatus*. Figs. 8 and 9 are portions of *Encrinites*, or "sea-

lilies," which are sometimes very abundant in the carboniferous limestone.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig 12.

Figs. 10 and 11 are fossil ferns known as Pecopteris,

and *Neuropteris*, which are found abundantly in the black shales adjoining the coal seams.

Fig. 12 is the stem of a reed-like plant known as *Calamites;* fig. 13 is the flattened stem of a large tree called by geologists *Sigillaria;* and fig. 14 is a portion of

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 17.

Fig. 18.—CROSS-SECTION OF THE BRISTOL COAL-FIELD. $\frac{1}{2}'' = 1$ Mile.

A, Old Red Sandstone; B, Carboniferous Limestone; C, Millstone Grit; D, D, Coal Measures, with beds of Coal. 1. Trias; *2, 3, 4, Lias*; 5. Lower Oolite.

the root of the same plant, which is frequently found in the "underclay." It is called *Stigmaria ficoides*, and is one of the best possible indica tion of coal.

Fig. 15 is a small branch of a kind of club-moss known as *Lepidodendron;* fig. 16 is a portion of the bark of a larger branch; and fig. 17 is its fruit, called *Lepidostrobus.*

8. Coal Basins. — Coal-bearing strata very frequently lie in "basins," or troughs, as shown in fig. 18, which is a section across the Bristol coal-field, on a scale of about one inch to one mile horizontal, and a somewhat greater vertical scale. In this section the manner in which the coal measures are contorted by the rocks beneath and capped unconformably by the rocks above is well shown. Fig. 19 is a cross-section of the Staffordshire coal-field, which is a district of great geological interest. The several coal-basins of England and S. Scotland are indicated by dark shading in the outline map at the beginning of this book. In several instances coal is known to exist beyond the limits indicated, but under so great a thickness of newer strata as to be practically out of reach, at least for the present.

9. British Coal-fields. — In the following table some interesting particulars relating to these coal-fields are given.

Fig 19.—Section across the Dudley Coal-Field, as actually proved in various Collieries, showing the "thick coal" and the chief faults.

TABLE OF THE BRITISH COAL-FIELDS.

*Giving their respective areas where the coal measures are exposed and where overlaid by newer formations, the estimated thickness of workable coals, etc.**

No.	NAME OF COAL-FIELD.	Area in miles of coal measures. Exposed	Area in miles of coal measures. Overlaid	Seams 2 ft. and upwards.	Thickness of workable coal in feet.	REMARKS.
1	Northumberland and Durham,	460	225	20	60	Much excellent household coal.
2	York, Derby, and Nottingham shires,	760	400	15	46	
3	Lancashire,	197	25	5 to 18	60	
4	Burnley,	20		..	46	
5	Flintshire,	35	..	5	25	
6	Denbighshire,	47	20	7	30	Contains also much excellent iron ore.
7	Shrewsbury and Clee Hills,	..	..	..	..	Small area, seams few and poor.
8	Coalbrookdale,	28	..	6	27	
9	Forest of Wyre,	..	..	1	4 to 5	Coal usually of inferior quality.
10	North Staffordshire and Cheadle,	75	20	22	94	Several valuable beds of clay, ironstone, and hematite shale.
11	South Staffordshire,	93	..	6	65	One seam of coal 30 ft. thick; beds much disturbed by basaltic rocks; great quantities of clay-band iron ore.
12	Warwickshire and Leicestershire.	45	137	11	26 to 55	
13	Forest of Dean,	34	..	8	24	This is a very perfect coal "basin" dipping inwards from all sides; contains in all 31 seams of coal and many beds of iron ore.
14	Bristol and Somerset,	45	105	20	71	
15	South Wales,	906	..	25	84	There are in this coal-field more than 100 distinct seams of coal and much clay-band iron ore. The eastern portion of the field yields highly *bituminous* or *house coal*, the centre *steam coal*, and the west *anthracite*. The millstone grit is here known as the "Farewell Rock," no coal having been found beneath it in South Wales.

* *Principally* from Hall's *Coal-fields of Great Britain*.'

TABLE OF THE BRITISH COAL-FIELDS—*Continued.*

No.	NAME OF COAL-FIELD.	Area in miles of coal measures. Ex-posed.	Area in miles of coal measures. Over-laid	Seams 2 ft. and up-wards.	Thick-ness of work-able coal in feet.	REMARKS.
16	Anglesey,	10	7	54	..	
17	Cumberland,	25	8	15	..	Several beds of iron ore known.
18	Dumfries,	..	..	..	..	These form parts of one great original coal-field, the coal occurring partly in the lower coal measures, but chiefly in the mill-stone grit and the carboniferous lime-stone shales. The Clyde basin contains many valuable beds of ironstone, including the celebrated "Black Band" stone.
19	Ayrshire,	..	..	..	..	
20	Clyde Basin and Clackmannan,	..	11	40	..	
21	Fifeshire,	1720	29	120	..	
22	Lothian,	..	28	100	..	
23	Lesmahagow,	..	..	..	..	

10. Estimated Quantity of Coal in United Kingdom.—Mr. Hull estimates that in Great Britain no less than 5431 square miles are stored with coal, without reckoning any existing at a greater depth than 4000 ft., and that there still remained, in 1861, more than seventy-nine thousand millions of tons of workable coal.

11. Recurrence of Coal Beds.—Beds of coal vary much in thickness, from less than one inch to more than thirty feet. In general it is only seams of two feet or upwards which can be profitably worked, but occasionally two thin seams occur so situated that the roof of the upper one may form the "roof," and the floor of the lower the "thill" of the mine, when they may be worked to advantage. A great succession of coal beds is sometimes met with, as in the South Wales coal-field, where more than 100 distinct seams are known, interstratified with beds of shale, sandstone, and ironstone; and each, as is universally the case, resting upon its own proper bed of fire-clay or "underclay."

12. Underclays, etc.—This underclay is evidently the

ancient muddy soil upon which the vegetable matter now converted into coal grew, and it is often full of *stigmaria*, formerly supposed to be distinct plants, but now known

Fig. 20.—SECTION OF STRATA AT THE NORWOOD NEW PIT, NEWCASTLE COAL-FIELD.

to be the roots of the *sigillaria.* Many of the beds of sandstone met with are "ripple-marked," by which it is known that they were sands deposited in shallow water. The section, fig. 20, shows the strata met with in sinking Norwood New Pit, in the Newcastle coal-field. The Beaumont seam, which there consists of two seams separated by a band of grey shale, was met with at a depth of 252 feet from the surface. The pit has since been sunk down to the Brockwell seam, which was struck at nearly twice that depth.

13. Variations of Composition in Coal Seams.—We have already stated that the Beaumont seam at the Norwood New Pit consists of two distinct bands of coal separated by a band of grey shale. At Wallsend Colliery it is made up as follows:—

Coal, - - - -	2′	11″
Greystone, - - -	0	4
Coal, - - - -	0	7
Greystone, - - -	1	3
Coal, - . - -	1	5
Total	6′	6″

Another example of variable composition may be referred to in the Five-quarter Seam at Pontop Colliery, which consists of

Coal, - - - -	0′	7″
Jet, - - - -		3
Coal, - - - -	3	2
Splint, - - -		8
Coal, - - - -	1	8
Total,	6′	2″

A still more complex seam is worked near Berwick Hill. It is made up as follows:—

"Dant" mixed with coal, -	0′	4″
Top Coal, - - - -	0	10
Danty black-stone, - - -	0	4
Middle Coal, - - - - -	1	3
Black Dant, - - - - -	0	2
Coarse Hard Stone, - - -	0	11
Coal, - - - - - -	0	10
Total,	4′	8″

Sometimes the same seam yields coal which may be advantageously separated before selling. The famous "Tophard" seam at Handsworth is thus composed :—

Roof Coal,	2"	This portion is thrown away, being useless.
Batt or black shale,	2	
Brassy piece (pyritous),	5	
Rough bright,	4	Used for house fires.
Best bright,	4	Good for making soft coke.
Top hard,	4	Good for steel-making.
Dead bed,	8	
Bottom hard,	1	
Rough bright,	6	For house fires.
Soft bright,	3	For soft coke.
Dirt parting,	9 to 12	
Holing coal	4	A very dusty soft coal.
Total,	55	

14. Varieties of Coal.—The following distinct varieties are likely to be met with in different or the same districts.

Anthracite—Hard and strong, with a shining fracture; does not soil the fingers; burns without flame.

Steam or Smokeless Coal—Less hard than anthracite, but much resembling it; burns with more or less flame.

Free-burning Coal—Still softer; burns with much flame, but does not cake together.

Caking Coal—Burns with much flame; gives off much smoke and cakes together; valuable for coke-making and gas-making.

Cannel or Candle Coal—Breaks with a smooth conchoidal fracture, and burns with a very bright flame; fresh fractures very dull; scarcely soils the fingers. The *parrot coal* of Scotland and the *rattlers* of Yorkshire are very similar, but they crackle much when heated. Very rich in gas.

Lignite or Brown Coal has a more woody appearance than true coal and is generally much lighter. Varieties are *pitchy* coal, *slaty* coal, *paper* coal, *needle* coal, etc.

Besides the above varieties of what are usually called coal-layers or bands of the following substances occasionally occur either alone or with beds of coal.

Bass or Batt—A black carbonaceous shale much like cannel but more earthy.

Jet—A substance very like cannel, but of a more glossy appearance.

Torbanite—A dark-brown, tough, compact mass, containing a large quantity of carbonaceous matter yielding occasionally as much as 16,000 cubic feet of gas per ton.

Swad—A black earthy or sooty substance, which occurs near basalt or whin dykes, and elsewhere.

15. Varieties of Rocks.—Some or all of the following different kinds of material will be met with in sinking through the coal measures and their overlying rocks.

Sand—Loose or compact.

Gravel—Of various degrees of fineness.

Silt, or hardened mud; usually greyish or bluish.

Clay—Of various colours and degrees of hardness.

Shale, Metal, or Bind—Much resembling hardened clay, but of a fissile or slaty character.

Sandstone or Post—When compact and not too hard this is called freestone in Scotland and the North of England.

Oolitic Limestone—This is the freestone of the south and centre of England.

Compact Limestone—Of various degrees of hardness.

Magnesian Limestone.

Gypsum, Alabaster, or Sulphate of Lime.

Fire-clay or Ganister—A highly siliceous hardened clay, well suited for making fire-bricks.

Chert—A hard rock of a flinty nature.

Marl or Marlstone.

Fire-stone—A soft kind of sandstone which resists the action of intense heat; used for lining furnaces, etc.

Clay Ironstone—Occurring either in beds or layers of nodules.

Brown Hematite.

Basalt, Whin, Loadstone, or Green Rocks—A hard and usually dark-coloured rock occurring in dykes or in sheets parallel to the beds of rock. The term is often applied to hard rocks which are not of the nature of basalt.

16. Variations of thickness in Carboniferous System.—The different members of the carboniferous system vary much in mineral character as well as in thickness in the several districts. In South Wales the coal measures are, in all, from 12,000 to 14,000 ft. thick; the millstone grit, about 1000 ft., and the carboniferous limestone 800 to 1500 ft. In the centre of England the carboniferous limestone is represented by the Yoredale rocks and the

Scaur limestone; and the great variations within quite short distances are shown in the following table :—

	Barnsley.	N. Staffordshire.	Leicestershire.
1. Coal measures, -	- 8460	6000	3000
2. Millstone grit, -	- 5500	500	50
3. Yoredale rocks,	- 4675	2300	50
4. Scaur limestone,	- 250	...	...
Totals,	18,885	8800	3100

CHAPTER III.

PROSPECTING.

17. Surface Indications.—In an unknown or imperfectly known district seams of coal may sometimes be discovered by a careful examination of the beds of rivers, the sides of ravines or railway cuttings, or the faces of sea cliffs. Sometimes the "basset edge," or outcrop of the coal itself, may be thus discovered; more commonly, however, only black shales containing impressions of fossil shells or ferns, more or less resembling figs. 3 to 17, will be found, the coal itself having decayed near its outcrop. Sometimes fragments of the underclay, containing portions of *stigmaria*, will be observed, and this will be a good if not an infallible indication. Occasionally, the situation of a coal seam is indicated by the outflow of a spring of water depositing much ochrey matter—the result of the decomposition of iron pyrites, or "brasses," in the joints of the coal, but this appearance may frequently occur without the existence of any coal. In some instances a darker shade of the ground, after ploughing, has led to the discovery of a bed of coal, but this sign can only be of value in a known coal-bearing district.

18. Fossils.—Coal of good quality in paying quantities has rarely been found in Britain unless associated with dark shales and fossils, resembling figs. 10 to 17, overlying

limestones with fossils, like figs. 3 to 9. No matter how black the shales may be, unless such impressions are met with, it will be a great risk to spend money in the search for coal. A disregard of this important fact has led to many costly undertakings in districts situated thousands of feet below the true "coal measure" horizon. In the absence of more detailed information, and this is very rarely to be obtained, the Government Geological Maps will, for those districts where the survey has been completed, suffice in almost every instance to prevent those who take them for their guides from being similarly misled in the future.

Fig. 21.

Fig. 22.

Fig. 23.

Fig. 24.

19. Negative Indications.—Should any rocks be found which contain fossils, resembling figs. 21 to 25, no money

should be spent in boring beneath them, as the chance of finding coal is, in Britain, hopeless.

Fig. 25.

20. Inclination or "Dip."—The amount of "dip" or "inclination" of some bed of rocks having well marked characters, and situated as near as possible to the bed of coal, should be most carefully observed, the rock traced for a considerable distance, and its thickness determined. Dips of from 0° to 90° are shown in fig. 26.

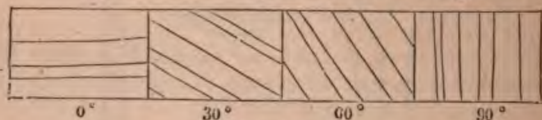

Fig. 26.

The following table will be of use in converting angles of dip into nearly equivalent statements suitable for practical application. It is extracted from a very useful little appendix on geological surveying, written by Mr. Geikie, of the Geological Survey, for Jukes and Geikie's *Manual of Geology*.

Angle of Dip.	=	Inclination of	=	Ft. or yds. in 100	=	inches in a yard.
1°	=	1 in 57	=	1¾	=	½
2°	=	1 in 29	=	3½	=	1
3°	=	1 in 19	=	5½	=	2
4°	=	1 in 14	=	7	=	2½
5°	=	1 in 11	=	9	=	3
6°	=	1 in 10	=	10	=	4
7°	=	1 in 8	=	12½	=	4½
8°	=	1 in 7	=	14	=	5
9°	=	1 in 6	=	16	=	6
11°	=	1 in 5	=	20	=	7
14°	=	1 in 4	=	25	=	9
18°	=	1 in 3	=	33	=	12
20°	=	...	=	36	=	16
24°	=	...	=	44	=	17

Angle of Dip.	=	Inclination of	=	Ft. or yds. in 100	=	inches in a yard.
26°	=	1 in 2	=	50	=	18
30°	=	...	=	58	=	21
35°	=	...	=	69	=	25
40°	=	...	=	83	=	30
45°	=	1 in 1	=	100	=	36
64°	=	2 in 1		...		...
72°	=	3 in 1		...		...
76°	=	4 in 1		...		...
79°	=	5 in 1		...		...
81°	=	6 in 1		...		...
82°	=	7 in 1		...		...
83°	=	8 in 1		...		...

In this table the nearest whole number is given, omitting fractions.

21. The Clinometer.—The amount of "dip" may be readily determined by the aid of the "clinometer," a rough form of which is shown in fig. 27. This little instrument is often combined with a compass, when it forms a most useful prospecting companion. Where great accuracy is desired, a straight piece of wood several feet in length should be placed between the rock and the lower edge of the clinometer. The observation so made will give aid in determining the proper positions of the trial borings, since the dip of the coal beds will almost certainly be the same as that of the containing rocks.

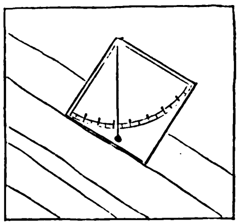

Fig. 27.

CHAPTER IV.

TRIAL BORINGS.

22. Position of Trial Borings.—The existence of the coal seam having been ascertained, or at least shown to be highly probable, trial borings may now be very

properly commenced. These borings should be made as far as possible in a direct line, at right angles to the line of "strike," or in the direction of the "dip" of the rocks, and closer together in disturbed than in undisturbed districts, as also where the dip of the rocks is great.

The preliminary examination of the country will have given some information as to the depth to which the bore holes will need to be carried; thus, if the required seam has been seen at a point, say 300 fathoms from the proposed bore hole, directly across the strike of the rocks, and the clinometer has shown the dip to equal, say, 1 in 6, the seam will, if undisturbed, be found 50 fathoms deeper in the new than in the old situation.

23. Occurrence of "Faults."—Special observations must always be directed to discover whether any "faults," "slips," "throws," or "troubles," exist in the neighbourhood of the proposed borings, as these may upset all calculations if not discovered in time. In some cases these faults throw the seams down many fathoms, as shown in fig. 28. Generally, if one such fault be known in a district others may be expected to occur parallel with it.

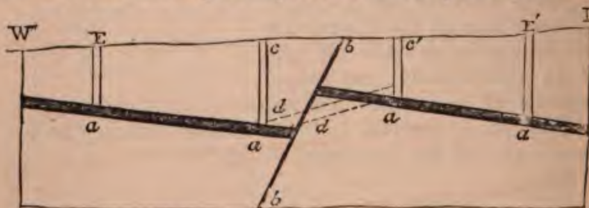

Fig. 28.—*a*, *a*, Bed of coal; *b*, *b*, fault; *c*, *c′*, *e*, *e*, bore-holes.

In disturbed districts, therefore, it is good policy to have very many bore-holes, as otherwise important dislocations of strata may not be discovered until much money has been spent in laying out useless or unsuitable works. A consideration of fig. 28 will show that the information to be derived from bore-holes may be seriously misunder-

stood if they be not sufficient in number, and if the true dip of the underlying rocks be not accurately known. Here a seam of coal, *a a a*, is thrown up to the east by an unsuspected fault, *b b*. It is plain that if bore-holes are only made at *c c*, the bed will be supposed to lie as shown in *d d*, but if the additional trials at *e e* be made, the true position of the beds will be at once known.

24. Importance of Ascertaining true "Dip."—Another illustration of the difficulty of obtaining trustworthy information from borings in certain cases, unless they are numerous, is afforded by fig. 29, which represents the strata met with in two bore-holes *a* and *b*, 120 yards apart, at the Cornforth Colliery, near Durham. In this instance there happened to be two seams of coal of similar appearance and nearly equal thickness, situated under a mass of new red sandstone, of variable thickness, which lay unconformably upon it. The seams cut being apparently similar and at nearly equal depths, it was natural to suppose them to be the same, and to lie as indicated by the dotted line, but subsequent sinking showed that this conclusion was erroneous.

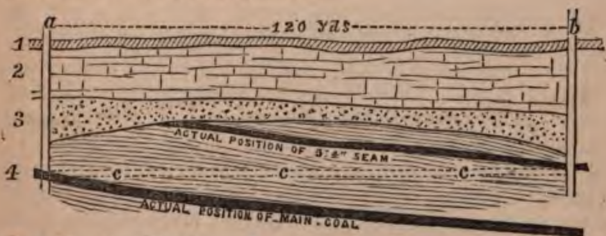

Fig. 29.—1, Alluvium; 2, magnesian limestone; 3, new red sandstone; 4, coal measures. *a*, bore-hole, 40 fath. 21 ft. 5 in.; *b*, bore-hole, 41 fath. 5 ft. 9 in.; c, c, expected position of 5′ 4″ seam.

25. The Boring Apparatus, as usually employed, consists of three principal parts, known as head-gear, tools, and rods.

26. Head-gear.—That commonly used in the north of England and South Wales consists of—

1. A triangle or shear-legs, fig. 30*a*.
2. A windlass or jack roll, fig. 30*b*.
3. A pulley block, fig. 30*c*.
4. A rope, fig. 30*d*.
5. A brakestaff, fig. 32.
6. A pair of tillers, fig. 31*a*.
7. A bracehead, fig. 31*b*.
8. A pair of runners or lifting dogs, fig. 33*a*.
9. A pair of keys, hand dogs, or rod-wrenches, fig. 33*b*.
10. A spring hook, fig. 33*c*.

The shear-legs or triangles, fig. 30*a*, are placed over the bore-hole for the purpose of supporting the block and ropes by which the rods are drawn out of or lowered into the hole, either for clearing or changing the tools. This raising and lowering is necessary many times each day, and much time is always taken up in this part of the work, and to reduce the loss as much as possible the rods are taken up in long lengths. For a deep bore-hole the triangle should not be less than 40 ft. high, and in addition a pit or staple should be sunk some feet, or fathoms, as the state of the ground may allow; and in this pit the man who has charge of the hole will be placed. Instead of this pit a strong staging or platform is sometimes constructed, having a hole in the centre through which the rods pass. Besides the saving of time in breaking joints thus secured, a still greater advantage is secured, since the actual depth of boring is by so much reduced, and with it the risk of accident. The total cost of the hole will also be much reduced, if deep, as the cost of boring increases progressively with the actual depth bored, and the effect of sinking, say, six feet at surface will be to save the cost of boring the last six feet. Occasionally, the bottom of a deep hole has cost as much as £12 per foot, in which case the saving would be very great. The shear-legs should be made of stout Norway poles, at least 8 inches diameter at bottom. Generally, they stand upon the ground, but they are often

jointed into a frame at the bottom, as shown in the figure.

The jack roll, fig. 30*b*, is sometimes made 12″ diameter, but 9″ will be found more manageable. One mode of attaching it to the triangle is shown in the figure.

The pulley block, fig. 30 *c*, is better single than double, as thereby a greater speed is attained. When the weight of rods is too great for two or three men at the windlass to overcome, it is better to apply machinery than to lose time in raising and lowering the rods.

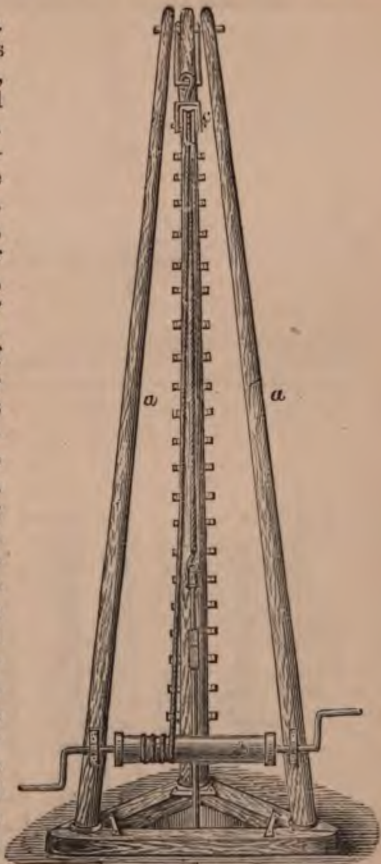

Fig. 30.

27. Mode of Working.—For holes up to about 5 fathoms in clayey ground, and 20 fathoms in dry ground, the brace-heads, fig. 31*b*, or the tillers, fig. 31*a*, may be attached to the rods at top, and will serve for raising them a few inches for each stroke of the chisel, the master borer giving the rods a portion of a turn while they are raised so that

Fig. 31*b*.

Fig. 31*a*.

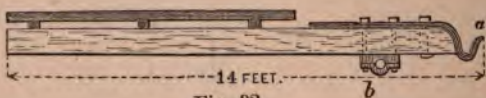

Fig. 32.

Fig. 35

Fig. 33.

Fig. 34.

the chisel may not fall twice in the same place. In very soft ground no lifting will be necessary, the simple turning of the heavy rods being sufficient. For greater depths, say up to 40 or 50 fathoms, the brakestaff or brake-beam, fig. 32, may be used. This is made of fir wood, from 10 to 15 ft. long, with a fulcrum about 16 in. from the end *a*, at which an iron crook is attached, the rods being suspended from this crook by a loop or by a short piece of rope. The fulcrum of the brake is an iron axle which works in the socket *b* on the under side of the brake.

28. Mode of using the "Brake."—The operation of boring with the brake is as follows:—The rods, with a chisel attached, are first lowered into the bore-hole, and the upper end attached to the iron crook of the brake. Two or more men depress the long end of the beam, as directed by the master borer, and so raise the rods a few inches; while they are raised the master turns the rods partially round, taking care to make the revolution in the direction of the sun, so as not to unscrew the rods; the men at the brake then leave go and the rods fall to the bottom of the hole, so cutting the rock. The master holds the bracehead or tillers in his hands, and can usually tell by the touch when any change in the stratification is met with, or when the rods must be raised to clear the tools.

29. Changing or Raising the Gear.—When it is necessary to change or clear the tools, the bracehead is unscrewed and a runner, fig. 33*a*, attached to the rope is passed under the swelling of the joint. By means of the jack roll the men who were at the break draw up the rods as far as the height of the shear-legs will allow, and the weight of the rods is then taken up by another runner passed below the lowest attainable point, which runner is suspended by a cross-pole from the surface of the pit or staple. The joint is then unscrewed by the key, fig. 33*b*, the rods released and laid aside, the runner again lowered, placed under the swelling of the joint, and the lifting of the rods repeated until the chisel is drawn from the hole, examined, and replaced or exchanged for another tool.

30. Deep Borings.—Instead of the brake a spring-pole may be used, with its outer end weighted; but as the hole becomes deepened it will generally be desirable to dispense with the brake or spring-pole, and to pass a rope once or thrice round the jack roll, leaving the outer end to be held by a man, and attaching the inner end by the swivel and spring-hook, fig. 33*c*, to the rods. The men at the windlass then wind up the rope, the man outside keeps the rope taut until the rods are sufficiently lifted, and then suddenly slackens it when the rope slips round the drum of the windlass, and the stroke is made. The men keep on winding in one direction, the man at the loose end alternately tightens and loosens his end, and in this way strokes are repeated very rapidly with a minimum of fatigue.

31. Tools.—The tools used are of four kinds :—

1. Chisels, augurs, etc., for cutting, breaking, or loosening the material at the bottom of the hole.
2. For extracting the loosened material.
3. For enlarging or equalising the hole.
4. For extracting broken rods.

1. *Chisels*, etc., are of several kinds, as shown in fig. 34; *a*, is a flat chisel for moderately hard ground; *b*, a V chisel for similar ground; *c* is a T chisel for hard and rocky ground; *d* is a shell augur for soft, sandy, or clayey, ground; *e* is a worm augur for loosening the bottom of the hole; *f* is a serrated tube for cutting coal by revolution.

2. *Tools for extracting the loosened material.*—The shell augur or wimble, fig. 34*d*, is sometimes used for this, but frequently the valved augur or sludger, fig. 35, is used for this purpose. A serrated tool like fig. 34*f*, but having two cutters and a valve inside, is also used for this purpose. In this form it is the invention of Mr. Stott of Ferryhill.

3. *Tools for enlarging and equalising the hole.*—For enlarging, a larger shell augur is used in soft ground, but in hard ground the chisel shown in fig. 36*a* is frequently

Fig. 36.

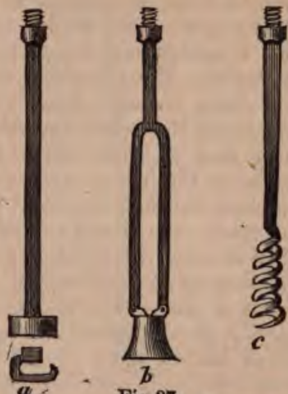

Fig 37.

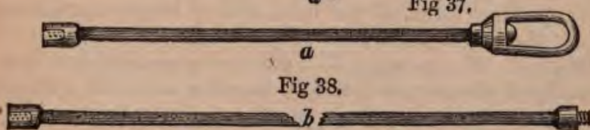

Fig 38.

Fig. 40.

Fig. 39.

used, in hard ground a T augur may also be used. For equalising the hole, a solid cone called a rounder, fig. 36*b*, with a square base is sometimes used, but this is seldom necessary. The rounder is made of steel well hardened.

4. *Tools for extracting broken rods.*—Occasionally, in deep holes, the rods are unable to bear the severe torsional strain and so break—more frequently a chisel or augur breaks in the hole—or a female screw gives way and the bore-hole becomes encumbered with the broken material. Sometimes the pieces cannot be recovered or removed, when it is necessary to sink another hole from the surface; but frequently the broken rods may be recovered by means of the crow's-foot, fig. 37*a*, the bell box or bèche, fig. 37*b*, or the spiral worm, fig. 37*c*, which are allowed to fall heavily upon the broken pieces, and often retain them until they can be drawn to the surface. There are many other forms of tool used in deep boring operations, but these can hardly be described in this elementary treatise. The rods, fig 38 *a* and *b*, are made of best iron, preferably square, in 5 or 6 ft. lengths, each with a female screw at one end and a male screw at the other. They are usually from 1″ to $1\frac{1}{4}$″ square, but for large and deep holes are sometimes made much larger. A few short matching pieces are often supplied for adjustment in making up lengths for convenient working. The female screw socket should always be made very strong, the thread stout, of not less than six turns.

32. Tubing.—In case of clay or quicksand, it is often necessary to line the sides of the hole with iron pipes. In such cases it is important to use tools sufficiently large to allow of the easy passage of the tubes, and near the surface these should be of considerable diameter so as to allow of the succeeding pipes sliding down through them. The pipes for this purpose are made in lengths, either with bayonet joints, as in *a*, fig. 39, or screw joints as at *b*. Three-inch pipes are ordinarily about 3s. per foot, but the price varies with the state of the market. When the bore-hole is completed these tubes may be sometimes

withdrawn by means of the spring dart, fig. 40, or with a solid tool called a box-key, which tapers from below, upwards, somewhat like a railway key. This is allowed to fall heavily into the tube, and then withdrawn, when it often brings up some of the tubes with it. In deep holes, however, the tubes are frequently lost.

33. Apparatus for Deep Boring.—A complete arrangement for working such a set of boring tools, as we have just described, to a depth of upwards of 1000 ft. is shown in fig. 41, where A is a large toothed wheel worked by spur-gearing from a steam engine or water-wheel. The mode of working will be clearly understood from the preceding paragraphs. At B is a series of weights intended to

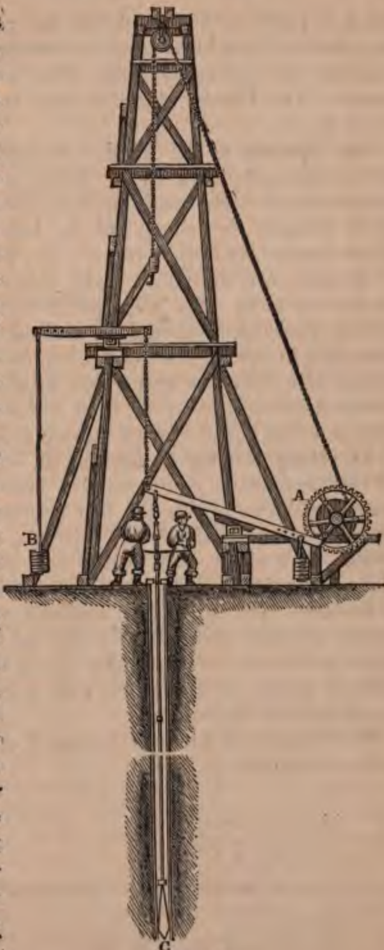

Fig. 41.

balance part of the weight of the rods, and to prevent the force of the blow from becoming excessive. These weights are increased from time to time, as occasion arises. The boring chisel is seen at C in the bottom of the hole.

34. System of M. Kind.—Several very deep borings have been put down by M. Kind, a celebrated German master-borer. The tools used do not greatly differ from those already described, but he has been able to reach great depths by employing a large wheel, some 16 to 18 ft. in diameter, and 8 ft. wide, this wheel being worked by twelve men. Six men place themselves *within* this wheel, working as though in a tread-mill, while as many more aid in turning it from the outside. The lever from which the rods are suspended is alternately raised and released by the action of four rollers, which are placed between two parallel discs on one side of the wheel.

35. Deep Boring at Cessingen.—M. Kind, by means of this apparatus, commenced a bore-hole at Cessingen, near Luxembourg, on the 6th February 1836, and completed it at a depth of 292 fathoms, on the 22nd March 1839. The upper part of the hole was a little under 9 inches diameter, while at the finish it was rather under 4 inches. The first 256 fathoms were put down by means of iron rods, but owing to frequent breakages from the weight of the rods, which appear to have been entirely unbalanced, wooden rods were substituted at the upper part of the column.

The strata cut through consisted of liassic and triassic rocks as follows :—

	fath.	ft.	in.
Lias Limestone, - - - - -	34	2	2
Luxemburg Grit, - - - - -	45	1	1
Sandy Marl, - - - - - -	13	5	5
Keuper Sandstone with Gypsum and Saliferous Marl, - - -	90	4	5
Middle Grit, - - - - - -	4	5	2
Gypsum and Saliferous Marl, - -	102	5	6
	291	5	9

The whole cost of this boring was 110,000 francs—equal to an average cost of about £15, 15s. per fathom, of which two-thirds only was directly spent on the boring. The sludge and broken rock were extracted from the hole by means of a valved cylinder attached to a rope, which was let down at intervals for that purpose. M. Kind has more recently carried a bore-hole to the great depth of 920 metres, or 3017 English feet, in the coal-field of Creuzot, in France.

36. Chinese System of Boring.—In this system solid rods are dispensed with, the tools being attached to a rope only, and allowed to fall by their own weight. The necessary gear is thus much simplified and reduced, and a more rapid progress is attainable, but the hole cannot be put down so straight as when rods are used. A very deep hole was put down in 1867 at Sperenberg, near Berlin, by a combined system, in which rope-boring had a share. The total depth of the hole was 4051 ft. 8 inches, of which the first 956 ft. were put down by manual labour and stiff rods, the remainder by means of ropes, to which were attached tools devised by Messrs. Fabian, Kind, and Zobel. The rocks bored through consisted of gypsum, anhydrite, saliferous marls, sandstones, and rock salt, and much trouble was experienced from falls of rock into the hole. The upper part of the boring was 15″, the lower 12″ diameter. The whole work was accomplished within 2349 shifts of 8 hours each, of which 1104 were expended in the actual boring, and 1245 in raising and lowering the rods. An average speed of nearly 2″ per hour was attained for the whole time, but the lower portion was executed rather quicker than this. The average cost was, for labour, 6 thalers, or a little more than 20s. per foot; for labour, material, and interest on plant, about 50s.

37. Mather and Platt's System.—A very successful modification of this system has been largely used in the North of England, South Wales, and elsewhere, by Messrs. Mather and Platt. In this arrangement the

boring tools are suspended from a flat iron or steel wire rope about $4\frac{1}{2}''$ by $\frac{1}{2}''$, by which means it is possible to raise or lower them with very great rapidity—the rope being wound upon a large drum with brake and reversing gear, and worked by a steam engine. The percussive action of the tool is produced by a separate small steam cylinder attached to the staging.

Fig. 42.

The cutting tool *a*, with its guides *b*, and rotating gear *c*, is shown in fig. 42. The cutters are readily replaced as they become worn or broken. The rotating gear *c* is very simple and effective, and depends for its action upon the elasticity of the flat wire rope; but space will not allow of a detailed description here.* The cutter makes a bore-hole from $12''$ to $3'$ diameter, as may be required. At intervals a small pump is lowered into the hole, and the water and debris pumped into it by raising and lowering it a few times, when it is drawn to the surface and emptied.

By means of this machine a boring $18''$ diameter was put down at Middlesborough, a few years since, in triassic sandstone, gypsum, and marl, to a depth of 1302 ft. In going through the red sandstone the maximum rate of boring was 13 ft. in 13 hours, and when the depth was upwards of 1100 ft. a rate of $3\frac{1}{4}$ ft. in 13 hours was attained. The actual boring occupied 569 hours, raising and lowerin the tools 1011 hours, and incidental labour 4621 hours (including 1200 hours pumping). The average cost was about 12s. per foot.

38. Methods of Beart and Fanvelle.—In these systems tubular boring rod is used, down which a stream of

is described in the Proceedings of the South Wales Institute *gineers.*

water is made to flow, of volume sufficient to carry off and bring up around the tool the debris. For holes of moderate depth, and where water is abundant, this plan has proved itself very successful.

39. Beaumont's Diamond Borer.—This consists of a system of rods, the lower portion of which is hollow and armed, or set with a number of points of diamond—the hardest substance known. This tool does not work like other borers, by percussion, but is made to revolve with greater or less rapidity according to the nature of the rock, by means of a steam engine or other source of power. In this way a solid core is detached and raised to the surface from time to time, which shows the character of the strata passed through far more accurately than is possible by any other mode. By this mode of boring greater speed is generally attainable than even by Mather and Platt's machinery. The following instance may be given for example. A bore-hole was commenced on the 7th October 1871, on the estate of the Stanghow Ironworks Company in Cleveland. In the first 15 working days a depth of 107 ft. was reached, 86 of which were driven through hard sandstone and another hard rock thickly studded with crystals of quartz. Another 12 days brought the bore-hole down 220 ft. more to the shale, overlying the ironstone for which the trials were made, a total depth of 368 ft. The weather now became very cold and the pumps were frozen, so that a delay of some days ensued. Operations were however resumed, and by the 16th December, a further depth of 321 ft. was attained, and a core of valuable ironstone brought to surface from this depth, in 60 working days. Another hole was commenced on the same property on the 8th June 1872, and completed at a depth of 641 ft. on the 25th July.

Of this system Mr. W. Cockburn, the engineer of these works, writes thus:—"In the old system of boring the debris was brought from the hole in small particles, and had to be put in an oven or before a fire and dried, and then submitted to inspection; and if metalliferous strata

was passed through, or required to be proved, the wearing of the chisels and rods was incorporated with the material brought up, and not unfrequently gave a value to the specimens brought out of the bore-hole, not at all in keeping with the bed wished to be proved. Under this system this difficulty is effectually disposed of, as a solid core of strata is brought up direct from the strata perforated."

40. Boring Contracts.—Trial borings are usually carried out by contractors, who provide their own skilled workmen, boring tools, and special plant, the mine owners finding engine or water power, and, frequently, labourers.

41. Cost of Boring.—The cost of ordinary trial borings at Newcastle in 1869 was

	£	s.	d.	
For the first five fathoms, - -	0	7	6	per fathom,
,, second ,, - -	0	15	0	"
,, third ,, - -	1	2	6	"

and so on, increasing 7s. 6d. per fathom on completing every five fathoms. These charges were for boring through ordinary sandstone, limestone, or other comparatively soft rocks. For very hard limestone, basalt, or other rocks of unusual hardness, or for holes of more than a few hundred feet deep, special agreements are made, the charges sometimes amounting to many pounds per foot.

The cost of bore-holes by Major Beaumont's Diamond boring machine was, in 1874, as follows:—

	£	s.	d.	
For the first 100 feet, - - - -	0	8	0	per foot.
,, second ,, - - - - -	0	16	0	"
,, third ,, - - - - -	1	4	0	"

and so on, increasing 8s. per foot at the completion of each 100 ft. up to the 15th, after which special agreements were made. Hard rocks are not here of so great consequence, and it is rarely the case that extra charges are made on this account. The cost is certainly much greater than by other methods, but this is generally more than made up by the greater speed attained, the superiority of the information gained, etc.

The charges quoted above are however, without doubt, very high, and this is owing to the method being the subject of a patent in the United Kingdom. This is evidently the case, since a boring was carried down by this method, in 1873, at the Midlothian Colliery, Virginia, to a depth of 826 ft. 9 inches in hard silicious felspathic and argillaceous sandstones and dolomitic limestones, at an average cost of little over 2 dollars, or say 8s. 6d., per foot —the wear and loss of the diamonds amounting to about 25 cents per foot of boring.

42. Comparative Statement of Cost.—The following comparative statement of the cost of several representative boreholes will be interesting and instructive :—*

PLACE.	DATE.	DEPTH IN FATH.	COST PER FATH.	SYSTEM.	REMARKS.
			£ s. d.		
Cessingen,	1836-9	292	10 10 0	Kind.	Triassic Rocks of average hardness.
Sperenberg,	1867	675	15 0 0	Zobel & Kind.	Rocks of average hardness.
Middlesboro',	—	217	6 5 0	Mather & Platt.	Rocks of average hardness.
Cleveland,	1872	107	9 12 0	Beaumont.	Oolite rocks of exceptional hardness.
Midlothian, Va.	1873	133	2 11 0	Beaumont.	Hard rocks.
Sussex,	1873-4	171	17 10 10	Beaumont.	Moderately hard rocks.

43. General Conclusions.—A very elaborate comparison of the cost, etc., of deep borings, in different countries, is given by Mr. Oswald J. Heinrich, superintendent of the Midlothian Colliery, Chesterfield Co., Virginia, U.S., in the *New York Mining and Engineering Journal* for May, 1874. Mr. Heinrich's conclusions are :—

1. That manual labour is not advantageous for depths beyond 150 to 200 ft.

2. That a flat wire rope is better than rigid rods for depths beyond 200 ft.

* The sub-Wealden boring in Sussex, the last on the list, included *many special* expenses.

3. That the system of Mather & Platt is preferable to the diamond drill for soft rocks.

4. That the diamond drill is most advantageous where the rocks are very hard, or where very accurate information is required.

5. That the small size of the diamond drill borehole renders tubing much less necessary in ordinary cases; but that such small holes are more difficult to tube when the necessity arises.

In most cases it will be better to sink a pit, or staple, from the surface before commencing the actual boring, since the calculation of price reckons from the commencement of the actual boring and not from the surface. If this staple be, say, 5 fathoms deep, it will enable a greater length of rods to be changed at one time, and so expedite the work; but it will also save the great cost of boring the *last* 5 fathoms of a deep hole.

CHAPTER V.

FAULTS, ETC.

44. Generally inclined Position of Coal Seams.—It has already been stated that the coal measures, with their accompanying beds of coal, do not usually lie horizontally, but are generally more or less inclined, the dip varying from a few inches in a fathom to angles which occasionally approach the vertical. They are also frequently liable to sudden interruptions as shown in figs. 2, 19, 43, etc.

45. Faults.—Such sudden changes of position, together with many others of a different kind, are frequently spoken of as slips, dykes, throws, troubles, balks, swellies, etc., and more generally as "faults." The word fault

is more properly applied to the sudden changes of position, or interruptions of continuity, already referred to, and in this sense it is always applied by geologists.

Faults or slips usually occur in series of two or more, having a parallel bearing, sometimes all dipping one way, but frequently dipping in opposite directions. Ordinary faults are like that shown in fig. 43, where *a a*, *b b*, are two beds of coal disturbed by a fault at *c*. In this instance the downthrow is towards the west, to which point also the fault is inclined. *Ordinary faults dip towards that side on which the downthrow of the beds is.* It will be observed that a borehole or shaft might be put down in the position *d d* without striking the coal at all.

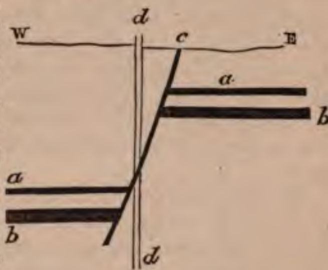

Fig. 43.

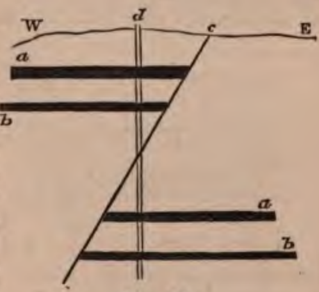

Fig. 44.

46. Reversed Faults or overlap faults are like that shown in fig. 44, where also two beds are disturbed. *In overlap faults the dip is on the opposite side to that of the downthrow.* The student will observe that a borehole or shaft in the position *d* would strike each seam twice.

The celebrated series of faults at Butterknowle Colliery, Durham, is shown in fig. 45. Here the main coal and the seams above it are faulted by no less than eight faults. The most northerly of the faults, known as the Auckland 70 fathom slip, "throws up" the coal to the north no

less than 70 fathoms, as shown at *a*. It will be observed that with all the other slips shown in the figure the dip of the coal seams is unchanged, but the seam to the north of the 70 fathom slip lies almost horizontal. The explanation of this fact, which is similar to what is observed in many other instances, belongs to Theoretical Geology. Many slips are known of even greater extent than that shown in the figure. Thus the great western boundary fault of the Lancashire coal-field has a downthrow west, or an upthrow east, of no less than 1500 yards.

47. Bearings or Directions of Faults.—In nearly every coal-field there appears to be several distinct systems of faults, but these are generally subordinate to some one chief system. Great faults are also sometimes accompanied by branch faults. In the following table the approximate bearings of the chief fault systems of several of the British coal-fields are brought into one view :—

District.	Direction.	Amount of Downthrow.	Remarks.
N. of England Great Tynedale,	E.W.	N. 90 to 180 fath.	
" Auckland;	"	S. 70 to 120 fath.	
Lancashire,	N.S.	..	
" Western boundary fault,	"	W. 1500 yds.	
" Great Up Holland,	"	W. 650 yds.	
" Shevington,	N.N.W.	N.N.E. 150 to 600 yds.	
" Cannel,	"		
" Great Haigh,	"		
" Great Pendleton,	"	N.N.E. 1000 yds.	
Coalbrookdale, Lightmoor,	N.S.	10 yds.	
" Great Boundary,	"	100 yds.	
S. Wales,	"	..	The principal slips are about magnetic N. and S. and remarkably parallel.
"	E.W.	..	
Anglesea,	N.E.S.W.	N.W. 766 yds.	
Denbighshire,	N.W.S.E.	..	Great Minera lead vein forms continuation of the principal fault of this district.
Lothian,	E.W.	..	Slips are generally transverse to troughs or synclinal axes.

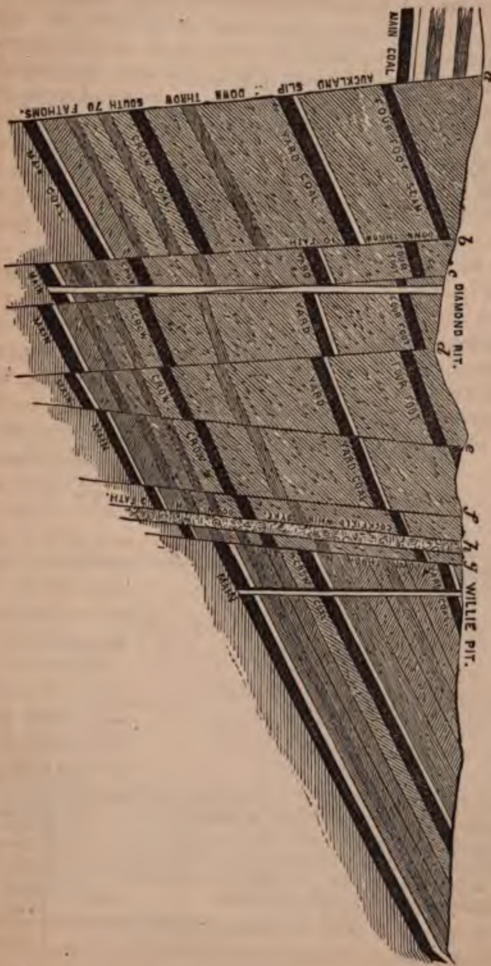

Fig. 45.—SECTION OF STRATA AT BUTTERKNOWLE COLLIERY, showing the Auckland 70 fathom and other slips, and the great Cockfield Whin Dyke.

48. Breadth and Contents of Slip Faults.—Slips or faults are occasionally so thin as to be easily mistaken for the ordinary jointing of the beds of rock which they traverse; more frequently, however, they contain between their cheeks, or walls, a space partially or entirely filled up by the debris of the adjoining rocks or other foreign matter. Very frequently they contain strings or pockets of iron pyrites (brasses), oxide of iron, or carbonate of lime, and where they traverse the coal seams quantities of cindery or sooty coal mixed with clay. In some districts zinc-blende, galena, or copper pyrites, is found in workable quantities, when the faults do not essentially differ from the fissure lodes of Cornwall or other metal mining districts. Thus the Great Minera lead vein is, in a part of its course, the principal fault of the Denbighshire coal-field. Another instance may be referred to which occurred at the Tyne Main Colliery, where, in one instance, 6 cwt. of galena was got from a slip by two men in 8 hours.

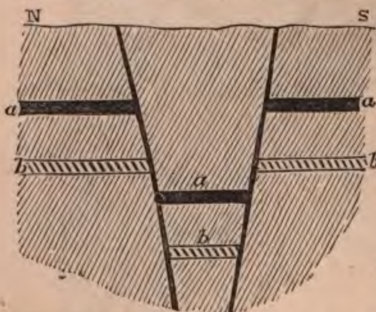

Fig. 46.—Section of a "Trough Fault" at Dudley Port, Staffordshire. *a, a, a*, 10-yard seam of coal thrown down 150 yards by a pair of slips forming a trough fault; *bb*, bed of basalt or green rock similarly faulted.

Many slips are very perplexing in their modes of occurrence, but the explanation of them belongs to the science of Geology, and cannot be entered upon here.

Slips are occasionally termed dykes, but they are quite different from true dykes, although they may accompany them.

49. Trough Faults consist of a pair of faults dipping towards each other as in fig. 46, where it will be seen that a portion of the seam is thrown down into a kind of trough.

50. Irregularities of Coal Seams.—"Balks" are sudden thinnings of the coal, occasioned by a depression of the roof of the seam, unaccompanied by a corresponding depression of the floor, or with a depression of less extent, as in figs. 47, 48. Some balks are occasioned by slips,

Fig. 47—SECTION OF A "BALK" OF THE SIMPLEST POSSIBLE FORM.

Fig. 48.—SECTION OF A "BALK" OCCASIONED BY THE COALY HILL DYKE AT BENWELL COLLIERY. *a, a, a,* Dyke of basalt; *b,b,* bed of coal.

as in fig. 49. When the balk is so great as to almost or entirely cut out the coal, it is called a "nip."

Fig. 49.—SECTION OF BALK AT BURNOPFIELD COLLIERY.

"Swellies" are the opposite of balks, the ordinary thickness of the coal being increased by a depression of the floor, as in fig. 50.

Fig. 50. — Ordinary "Swelly" occasioned by a Depression in the Floor of the Seam.

"Bad Coal" is a generic term applied when the seam changes its character and becomes soft, sooty, cindery, or banded with clay, pyrites, or shale, or shattered into fragments. Such changes of mineral character or condition are frequent in the neighbourhood of the dykes presently to be described.

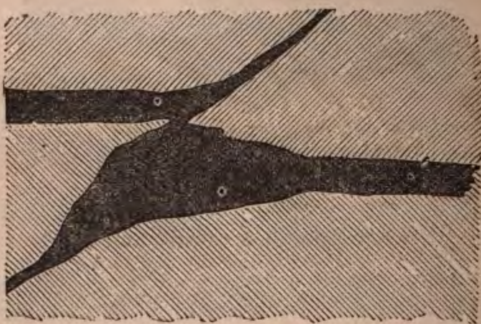

Fig. 51.—"Swelly" occasioned by a Fault in the "Bull" Vein at the Radstock Colliery.

Other irregularities in the coal seams, which may be here mentioned, are illustrated in figs. 52, 53, 54. The bending of the seams by a fault is shown in fig. 52. A zig-zag condition of the beds in some of the Continental fields is well shown in fig. 53.

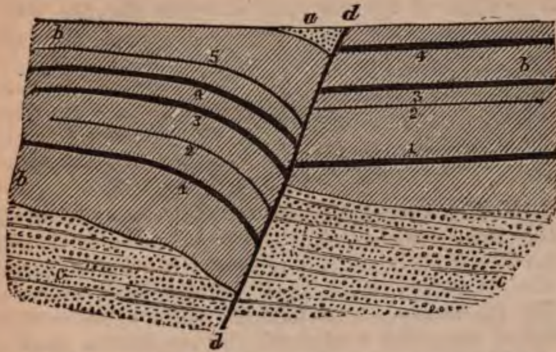

Fig. 52.—Bending of Coal Seams at Gosforth. 1, 2, 3, 4, 5, beds of coal; *a*, red sandstone; *b*, coal measures; *c*, millstone grit; *d,d*, fault, with downthrow N. 180 fath.

Fig. 53. —Section showing the condition of the Mons District of the Belgian Coal-Field.

Fig. 54.—Section of the Beaumont Seam, Norwood Colliery.

A junction of two seams is shown in fig. 54.

At right hand.	ft.	in.	At left hand.	ft.	in.
Coal, ...	2	7	Coal, ...	1	9
Band, ...	0	3½	Band, ...	5	9
Coal, ...	1	0	Coal, ...	0	9
	3	10½		8	3

51. Horses, horse-backs, or rock faults occur in several of the British coal-fields. The best known of these is in the Forest of Dean, and it occurs in what is known as the "Coleford High Delf" seam. It is described by Sir H. Delabeche as follows: "The horse with its branches resembles a channel cut amongst a mass of vegetable matters in a soft condition. It ranges S. 31° E. for a length of two miles and a breadth of 170 to 340 yards, a number of minor channels communicating with each other and the main channel are called "lows." The main channel has been compared to the bed of a river and the lows to its branches or tributaries, which cut to a less depth. The channels are filled principally with sandstone, which is the rock forming the roof of the coal in the neighbourhood." Others of these horse-backs occur in the Leicestershire coal-field and elsewhere.

52. Dykes consist of wall-like masses of basaltic rock which traverse the coal seams and their accompanying shales and sandstones. The material of which they are composed is variously known as green-rock, whinstone, toadstone, trap, etc. Sometimes these dykes pass through the strata without being accompanied by a slip or fault, as in fig. 55.

Fig. 55. — Cockfield Whin Dyke, Spitaltongues Colliery.

The dyke at Spitaltongues Colliery, fig. 55, is 40 ft. wide, it is composed as follows :—

a, cindery coal, ...	6 feet,
b, hard basalt, ...	12 ,,
c, loose sandstone and shale, . .	18 ,,
d, cindery coal, ...	4 ,,
	40 ,,

Very frequently the dykes coincide with faults, as in fig. 56, where *a* is a wall of hard basalt 9 ft. thick, *b* a mass of loose basaltic substance and debris 10 ft. 8 inches thick, and *c* another mass of hard basalt 4 ft. thick.

The same dyke at Benwell Colliery causes a balk, as shown in fig. 48.

53. Injurious Effects of Dykes.—As already mentioned, dykes are very frequently accompanied by cindery or bad coal, and beds of coal traversed by dykes are often injured to considerable distances. An instance of this occurs in connection with the great Cockfield dyke shown in fig. 55. This is the most important dyke in the north of England; it runs from Cleveland in Yorkshire to and beyond Cockfield Fell, in a direction generally about 45° west of north, dipping N.E. about 15″ per fathom. At Butterknowle Colliery it is about 7 ft. thick, but at Cockfield Fell Colliery and at Langbargh, near Cleveland, it is nearly 10 times as wide. At Cockfield Fell Colliery the dyke intersects the Bitchburn 7 ft. seam, at a depth of 25 fathoms from the surface. At about 50 yards from the intersection, on either side, the coal becomes dull, brittle, and broken, and the thin layers of carbonate of lime disappear from the joints. As it approaches still nearer the dyke, the coal becomes more and more cindery, and

FIG. 56.—HARTLEY WHIN DYKE FAULTING TWO SEAMS OF COAL.

diminishes in thickness until at last it is only 9 inches thick, and consists of a hardened sooty mass known as "Dant," or "swad," by the miners. The actual dyke is bounded on either side by a wall of clay of 6 to 12 inches thick, which serves as a dam to keep back the water. In this colliery the dyke is also a slip, the strata being thrown up to the south-west about 3 fathoms, but at some points of its course no displacement of the strata is observable. Some dykes traverse the coal in an almost horizontal direction, the dyke being nearly parallel with the seam. In such cases the quantity of damaged coal is proportionately greater.

54. Bearing of Dykes.—The bearing and underlie of dykes varies as much as those of slips. The chief dykes of the North of England have directions varying from N. 82° W. to N. 45° W., the average being about N. 60° W.

CHAPTER VI.

OF SHAFTS AND SHAFT-SINKING.

55. Position of Main Pits.—Having at length determined the depth and dip of the coal seams with accuracy, the miner is now enabled to fix the position of his chief shafts or pits, so as to work the mine in the most economical manner. With beds of coal lying as in fig. 2, these would be better placed as at *a* or *b* than at *c* or *d*. Such positions are chosen that the coal tubs may descend to the pit by their own weight to save haulage, and very often the empty tubs are carried back up the incline by the weight of the descending tubs. This mode of "working to the rise" is now almost universal.

It is true that such a situation for the pit renders a natural ventilation somewhat more difficult, as will be seen from a consideration of the chapter on that subject;

but in coal mines where an artificial system of ventilation is always adopted, this is of little importance. In many of the older collieries of S. Wales and elsewhere, the system of working downwards, or "working to the dip," was adopted, and this so much lessened the difficulties of ventilation that disastrous explosions were formerly much less frequent than of late years.

56. Form of Shafts.—The most common form for the "shafts" or "pits" of coal mines is circular, but they are occasionally made rectangular as in metal mining, or even polygonal, and many of those more recently sunk are elliptical, which is probably the best possible form, affording, as it does, the most convenient working space for a given area, and being also a very strong form. Circular shafts vary from about 8 to more than 20 ft. in diameter, but a good working size for a large output of coal may be taken at from 12 to 15 ft. As it is now compulsory in Great Britain to have, at least, two shafts in all collieries, except those provided with an adit level, very large-sized pits are now less necessary than they were in times when only one was sunk, and afterwards divided by bratticing into an upcast and downcast portion.

57. Commencement of the Sinking.—In starting a new colliery it will generally be advisable to commence a pair of pits at the same time, and pretty near each other, if the result of the trial borings will warrant such a course. The work will probably be done by contractors, and in making the contracts the manager will be guided as to price, as well as in his provision of materials and tools, by the information afforded by the trial borings. Unforeseen difficulties, however, are almost sure to arise in every considerable sinking, so that it will be well for him to provide for more than what is indicated by the borings, that there may be no delay at critical periods.

58. Transit Arrangements.—It will frequently happen that the sinking must be started at a considerable distance from any road. In such cases it will be well to

construct a road for the more ready conveyance of tools and materials. Of course this will be less necessary if a permanent arrangement of a railway or siding is contemplated for carrying away the coal when it is reached; but even in this case the cost of making a moderately good road will be saved in the more convenient and cheaper transit of stone, timber, etc., for the sinking which will result. In many instances a light tramroad may be laid on the surface without previous preparation by cutting or embankment which will serve every purpose.

59. Surface Sinking and Tubbing.—The first portion of the sinking will frequently be in soft ground requiring timber support. The pit is marked out about 2 ft. larger than the intended size when finished, and the ground removed by pick, or "hack," and shovel. For the first 6 ft. the men will be able to throw the earth to the surface as it is loosened, and by the erection of an intermediate staging that from the next 6 ft. also. While this is being done several wooden frames or "cribs" are

Fig. 57.

prepared in sections, like fig. 57. These cribs are best made of oak or elm, a good size being $5\frac{1}{2}''$ square. The segments are fitted together at the surface, and then sent down and strongly nailed together in the pit by means of the overlapping cleats. The first crib is placed on the bottom of the pit, and the "backing deals" of fir, about 9 ft. long and 7 or 8 inches wide, and 1 inch thick, are placed behind it, between it and the earth, thus projecting at surface about 3 ft. Another crib is then put

together while resting on the first, and then raised up some 2 or 3 ft. and supported by "punch props," as shown in fig. 58 at *e*. With ordinary ground, two cribs per fathom will suffice, but in tender ground it may be well to use three to the fathom, and to back them up with backing deals of $1\frac{1}{2}$ or 2 inches thick. It will be seen that these cribs represent the "sets" used in shafts for metal mining, in Cornwall and elsewhere, while the backing deals represent the "laths."

Fig. 58.—*a*, *a*, Hanging balks; *b*, *b*, cribs; *c*, *c*, backing deals; *d*, *d*, stringing deals; *e*, *e*, punch props.

The earth thrown out in the sinking is piled up around the projecting 3 ft. of the backing deals, so as to raise the mouth of the shaft to that extent above the general surface of the ground, this elevation will be useful to keep the surface water from running into the shaft, and will also serve for a "tip" for the stuff drawn out. When this is done another 6 or 9 ft. is taken out from the bottom to the size of the finished pit, say 14 ft. The bottom is then cut out to the size first marked out, say 16 ft. 9 inches, and another two or three cribs put in with their backing deals and punch props, the clay being gradually cut out, upwards, until the first crib put in is reached. During this process, "stringing

deals" or battens, *d d*, fig. 58, are nailed over the three cribs already in, so as to keep them in their right places. Occasionally, it is necessary to suspend the whole of the timbering from balks placed at the surface, as shown in the fig. at *a*, *a*. The cost of timbering, as described, in ordinary ground with two oak cribs per fathom, say a pit 14 ft. diameter, when finished will not be less than £8 per fathom, and may be as much as £11. Where elm is to be obtained cheaply, say for 2s. per foot, a considerable saving will be effected in the cost of the cribs—the most costly part.

60. Pile Sinking.—Sometimes it is necessary, where the stratum is very loose, to commence the pit of a very large size, beginning by driving a row of piles close together and puddling well behind with clay, as shown in fig. 59. In this figure the piles are shown at *b b*. This mode was adopted in sinking the pit at Framwellgate Moor Colliery, near Durham, where the pit was commenced 30 ft. in diameter, and afterwards reduced to 15 ft. in several successive stages. Such works are very costly, and where the loose sand or mud is proved to be very deep by the trial borings, should only be commenced when no other suitable position for the shaft can be secured. Alluvial deposits are sometimes very difficult to sink through, the pressure on the timber being so great that the whole pit falls together. An instance of this which occurred at the Norwood Pit, which was sunk through the alluvium of the river Team in 1851, is described in great detail by Mr. Greenwood.*

61. Sinking in Stone.—The first contract will generally take the sinkers through the loose ground or clay to the "stone-head." As soon as the rock appears to be sound it should be cut back nearly 5 ft. larger than the finished size of the pit and accurately levelled. The bed so formed is laid with planking, and a large "wedging crib" of stone or iron is laid upon it in segments and firmly wedged into its place. Should the crib reach the nett size of the pit

* *Practical Treatise on Mine Engineering*, pp. 160-162.

too soon, pieces of oak are placed between the joints and iron wedges driven into these until the segments are as tightly wedged as they can possibly be.

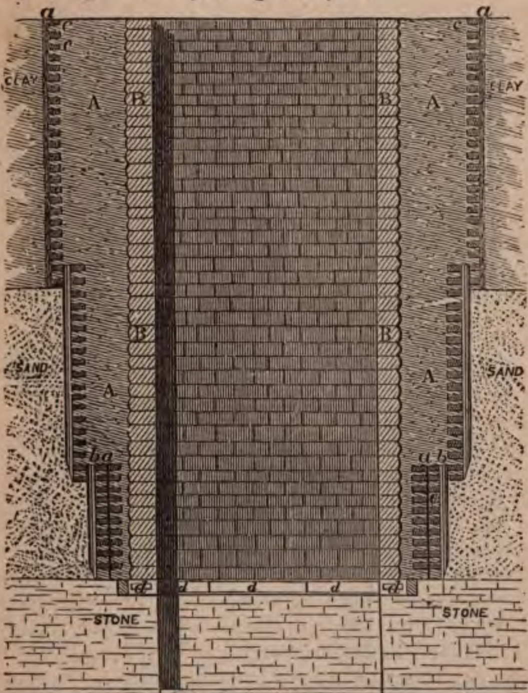

Fig. 59.—*a,a,a,* Backing deals; *b,b,* piles; *c,c,* wood cribs; *d,* iron cribs; A, space stowed with puddled clay; B, stone walling.

62. Walling of Stone or Brick.—Below this first iron or stone crib the timbering often gives place to walling, either of stone or brick, according to the resources of the neighbourhood. When stone is used it should be accurately dressed to its true form on its face—its two

beds and the two end joints. When good clay is obtainable, bricks should be moulded to the right form, and the walling so executed will be found very effective. Occasionally, they may be made of the clay taken out of the first sinking and burnt on the spot. Sometimes large blocks of fire-clay are moulded into the proper form and burnt, and this forms a most excellent walling, a little dearer than ordinary bricks, but cheaper than dressed stone.

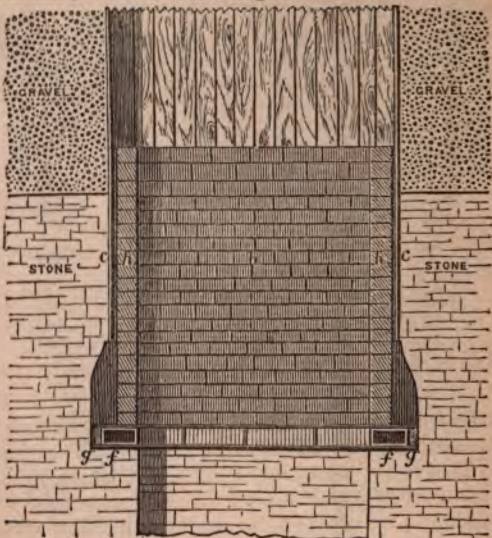

Fig. 60.—*c,c*, backing deals; *f,f*, metal wedging crib; *g,g*, wedging pieces of oak; *h, h*, stone walling.

The wall should be laid in good lime or cement, and well puddled with clay behind. It is built from a cradle or platform, suspended from the pit's mouth by ropes or chains, which is lowered or raised as required. This cradle is the same shape as the pit, circular or oval, as the case may be, and about one foot less in diameter.

The cost of walling a pit 14′ in diameter, as shown in fig. 60, with stone will rarely be less than £15 to £17 per fathom, and may reach £20; brick walling may probably be one-third less when the materials are at hand.

63. Metal Tubbing.—If the water becomes now considerable in quantity, it may be necessary to resort to metal tubbing, as in fig. 61, the sides of the pit being dressed very true, and the cribs, as before, put in in segments with wedging pieces of oak between the joints.

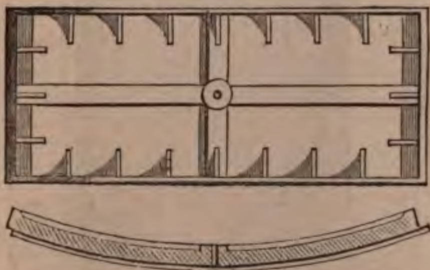

Fig. 61.—SECTION AND BACK ELEVATION OF CAST-IRON TUBBING. Scale $\frac{1}{2}''$ = 1 ft.

The cost of such a wedging crib will often be £50 or £60, and occasionally something like £100. The tubbing plates (fig. 61) are then placed upon the crib in order, the joints being broken as in fig. 62. Every plate has a hole in the middle to afford vent for water until the whole is complete, and is cast with strengthening ribs as shown in the figure. Each plate has also a flange at the back of the upper side, and one edge to keep the sheathing and adjoining segments in place. Pieces of wood are placed behind the tubbing plates, between them and the side of the pit, so as to cover the joints, and wedges are driven behind these to bring the plates into their true places. Pieces of wood are also placed between all the joints, vertical and horizontal, which, being brought together under pressure,

make them tight. The holes in the tubbing plates are plugged up last of all, and sometimes pipes are placed in one or more of the upper plates to relieve the pressure by giving vent to the water. The cradle used in walling is also used for tubbing.

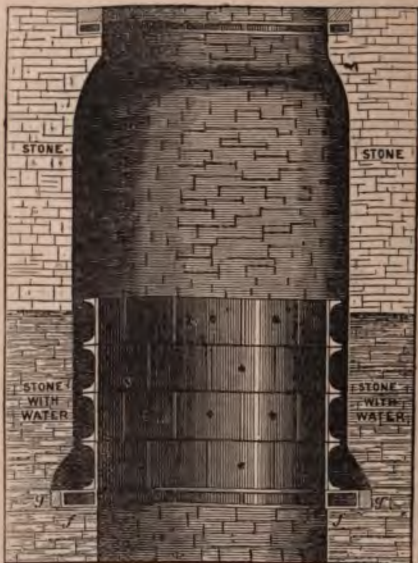

Fig. 62.—*f*, wedging crib of iron; *g*, oak wedging pieces; *k*, iron tubbing.

64. Thickness of Metal Tubbing.—If castings could be obtained without faults of any kind, it would be suffi-
cient to increase the thickness proportionately to the
: in other words, the pressure to be resisted—
lied by the diameter of the pit. As, however, such
s are not obtainable, it is necessary to modify such

a calculation by adding a constant. Mr. Greenwood gives the following formula for practical use.

Let P = vertical depth *in feet.*
,, D = diameter of pit *in feet.*
,, x = thickness of plate required *in feet*; then

$$x = \cdot 03 + \frac{PD}{50,000}$$

The following table is calculated by means of this formula for ready reference, the thicknesses are given in inches and decimal parts of an inch.

DEPTHS.	DIAMETER OF PIT.					
	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.
10 fathoms,	·504	·518	·532	·547	·561	·576
20 ,,	·648	·676	·705	·734	·763	·792
30 ,,	·792	·835	·878	·921	·964	1·008
40 ,,	·936	·993	1·051	1·108	1·166	1·224
50 ,,	1·080	1·152	1·224	1·296	1·368	1·440
60 ,,	1·224	1·310	1·396	1·483	1·570	1·656

65. Cost of Metal Tubbing.—This varies of course with the price of iron; but the cost of such tubbing for a pit 14 ft. diameter, rather under an inch thick, will be from £50 to £60 per fathom, exclusive of lowering and fixing, which may increase the cost by £10 to £20 per fathom. In shafts smaller than 14 ft., the less expensive stone or brick walling will usually suffice to keep back the water, and occasionally for shafts of no great depth a tubbing of stout planks or of solid cribs, placed one upon another, may be used successfully, but in larger shafts iron is now almost exclusively used. The metal tubbing may perhaps be needed only in portions of the pit, at other times all the way down until the seam to be worked is reached, when of course the cost of the pit will be very greatly increased.

Occasionally, tubbing consisting merely of planks nailed inside wooden cribs very carefully laid, without backing deals, is found sufficient, and in very loose or troublesome ground a solid tubbing made up of a succession of cribs

resting upon each other has been found very valuable. The deeper the shaft, if the ground be at all loose or wet, the stronger of course is the tubbing required; and although a tubbing of solid cribs is very expensive, it is much cheaper than metal tubbing, and strong enough to resist a pressure of 150 lbs. per inch, corresponding to a head of 50 fathoms; and where the water is corrosive it is much to be preferred. The enormous quantity of water described as occurring at Newcastle, in Art 71, was stopped back by a solid tubbing of 9″ cribs.

66. Inclined Drifts.—Highly inclined beds of coal, such as many of those found on the borders of the South Wales, Somerset, and other coal-fields, are sometimes worked by means of inclined drifts following the dip of the beds, as in many metal mines, in place of vertical shafts. Such drifts are seldom or never lined with metal tubbing, and not often with solid masonry. They are frequently rectangular, 8 to 12 ft. wide, and 6 to 9 ft. high, and strongly timbered with "pairs" or "sets and laths," in the same manner as that shown in fig. 63.

Fig. 63.

67. Ventilation of Pit Sinkings.—After the first 20 or 30 fathoms are sunk, and sometimes much sooner, the air frequently becomes very foul in the bottom of the pit. Usually the division of the shaft longitudinally, by a "brattice" of wood or painted canvas, is sufficient to determine a current of air down one side and up the other, and the current may be increased, either by keeping the men at work on one side only of the brattice at one time, so warming that division somewhat, or by lighting a small fire in one division. In old times, when collieries were worked from one pit, this brattice partition was permanent, but now that it is compulsory to

have at least two shafts, it is only a temporary contrivance to be used until a communication between the two shafts can be effected, when some one of the systems of ventilation described in the chapter on that subject is adopted. Occasionally, it may be desirable to force air down to the bottom of the pit, or to draw out the foul air by some mechanical means. Several contrivances for this purpose will be described in a future chapter.

68. Construction of Bratticings.—A temporary brattice may be very readily constructed as follows: "Buntons" of fir 2 inches thick, 4 or 5 inches wide, and long enough to reach from side to side of the shaft, are nailed at intervals of 3 or 4 ft. to the oak cribs, or else placed in notches cut for their reception in the stringing planks shown in fig. 58, and secured with iron nails or oak dowels. One or two thicknesses of "brattice-cloth," a kind of painted canvas made for the purpose, is now nailed to the bunton, and the brattice is complete, at a total cost of little over £1 per fathom for a pit 14 ft. diameter. Instead of the brattice-cloth, one inch deals, having their edges planed, may be nailed securely upon the buntons side by side. The cost of this will be from £1, 10s. to £2 per fathom.

The same kind of brattice, if required permanently, may be made of buntons 3 inches thick and 5 inches wide, covered with 2 inch planks tongued and grooved, or having their joints covered with narrow slips one inch thick. The cost of this bratticing will be nearly twice that just described.

One of the best forms of brattice is that known as the "plank brattice." It consists of a succession of 3 inch planks placed across the pit, bunton fashion, resting edge upon edge, and kept in place by a double series of stringing planks. If the plank brattice is to be applied to a shaft lined with metal tubbing, grooves for the reception of the planks may be cast in two rows of the tubbing plates. The cost of a plank brattice will be from £3 to £4 per fathom.

69. Timber used in Mines.—The best kinds of timber for use in mining operations are oak, elm, larch, Norway fir or red deal, Swedish or yellow deal, and American pitch pine. The oak and elm are not often required of very large size. These hard woods are used chiefly for cribs, and the price will be usually from 3s. to 4s. per cubic foot. Norway fir is very valuable for all underground work, as it is very strong and will bend considerably before breaking, so giving timely warning of impending accident. Its price at the port of entry is usually from 9d. to 1s. per foot. It is imported in the round state with merely the bark stripped off and the ends squared. Swedish timber is usually imported in square balks, of a somewhat larger size than that from Norway. Being squared and large it cuts to more advantage into battens, backing deals, etc., than the Norway, so that although it is about 1s. 4d. per foot at the port of entry, it is not really much dearer in actual use. It is not quite so strong as Norway timber.

American pitch pine reaches this country in very large balks, suitable for such purposes as making main rods for pumping engines. It is a very durable and strong timber, but of rather a high price, from 1s. 9d. to 2s. 6d. per foot. Occasionally, when exceptionally long and large, a much higher price than this is given.

For use as sleepers for tram roads, and for many other purposes, the small oak and fir poles, which may often be obtained where plantations are being thinned, will be found very economical. For sleepers they may be merely cut down longitudinally, the flat sides laid to the ground and the tram-rails nailed to the round sides. Oak poles fit for this purpose may sometimes be got for 10s. to 12s. per ton.

CHAPTER VII.

MACHINERY USED IN SINKING SHAFTS.

70. Raising of Debris.—We have already mentioned that for the first twelve feet, or "two throws," the earth may be thrown out by the men. From that depth downwards some kind of machine is necessary to keep the pit clear of debris. To the depth of 5 or 6 fathoms a hand windlass, or "jack-roll," will perhaps be most useful; but for greater depths a "horse-gin," or "whim," will be preferable, or else a portable engine, unless the engine for permanent haulage is on the ground, when this may be at once got to work.

71. Raising Water while Sinking.—The water met with in sinking is usually raised in tubs holding from 60 to 300 gallons, but as it increases some arrangement for pumping will often be indispensable. Occasionally, the quantity of water flowing into the pit is enormous; thus, at the C pit of the Wallsend Colliery at Newcastle, in 1786, a feeder of 1700 gallons per minute was met with at a depth of 30 fathoms from surface, a quantity so great that continuous pumping became necessary, in order that the men might continue their work in the bottom.

In modern sinkings, "direct-acting" pumps hung on cross-bearers, and supplied with steam from the surface, are often used while sinking. These and other contrivances for raising water will be described in a future chapter. The pits are always sunk some yards deeper than the deepest workings within the mine are intended to be so as to form a "pound," "standage," or "sump," for accumulating the water in case of a temporary stoppage of the pumps through accident, or for repairs.

72. The Windlass or Jack-roll.—This is usually made on the spot by the mine-carpenter. Its construction is

as follows: Two pieces of "half-timber" *g g*, fig. 64, are selected and placed across the shaft, which is here shown square. These are called the bearers, and they are afterwards planked over except the small space in the centre required for working the kibble, or sinking corves. In the middle of these half-timber bearers the uprights, *b b*, are morticed. These may be made of planks 4 ft. 6 inches long, 10 to 12 inches wide, and $1\frac{1}{2}$ to 2 inches thick. In the upper end of each upright a slot about 10 inches long and $1\frac{1}{2}$ inches wide is cut, and the bottom lined with iron to receive the iron handles and keep the wood from splitting. The barrel *c* is made of a piece of Norway fir 8 to 10 inches thick. The ends of the barrel are strengthened with iron bands to prevent them from splitting when the iron handles are driven in. The handles *d d* are made of 1″ or $1\frac{1}{2}$″ round iron bent twice at right angles, as shown, and squared and tapered at one end for driving into the barrel, for which the handles serve also as an axle. The parts by which the men take hold should be not less than 12 inches long. A piece of wood *e* is then fastened across the top, and a groove is made in it to receive a sliding piece *f*, which being pushed out beyond the bend of the handle holds it when required, keeping the load from descending. The stays *a a* are fixed extending sideways from the uprights *b b*.

Fig. 64.

Fig. 65.

The cost of such a machine should not exceed £1, 10s. to £1, 15s., for timber, iron-work, and labour. Another still simpler form of jack-roll, sometimes used for small sinkings, is shown in fig. 65. The construction of this is evident from the figure.

73. The Derrick, or Whipsy-derry, is shown in fig. 66. Its first cost is low, and by its means considerably greater weights may be lifted than by the jack-roll; but it is slow and inconvenient in operation, and far inferior in efficiency to the horse-gin or whim. Its cost is from £2, 10s. to £4.

Fig. 66.

74. The Horse-gin or Whim.—This is a very convenient and powerful contrivance for hauling stuff or raising water from moderate depths. An excellent form of this machine is that so common in the metal mines of the West of England, shown in fig. 67. The mode of

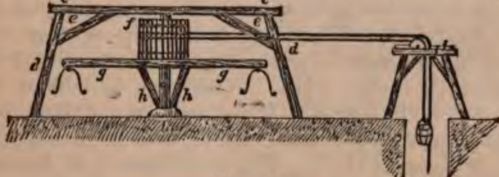

Fig. 67.

construction is as follows:—The axle *a* is of oak, about 12″ diameter, and 12 or 14 feet long. Three sets of arms are morticed into this at distances of 6, 8, and 10 feet from the lower end. Upon these arms wooden

segments are nailed, and upon these again the 4-inch planks which form the barrel or cage. Each end of the axle is bound with iron, and each has an iron centre attached. The lower one works in a block of stone, shown at *b*, the upper in an iron socket fixed to the span beam *c c*. This is made of a piece of Norway or Swedish fir, 36 feet long and about 10 inches square, supported by the legs *d d*, which are morticed into the beam, and frequently strengthened with iron strapping plates. Stays are added at *e e*. The barrel *f f* is 10 feet diameter; beneath it is placed the driving beam *g g*, 30 feet long, and strengthened by the stays *h h*. At one or both ends of the driving beam a bar of iron is fixed with a yoke to which a horse may be attached. The total cost of the whim here described is under £20, and it is a very efficient machine indeed.

75. **The Pulley Frame or Poppet Head** is shown over the shaft to the right of the whim. The construction is as follows:—Two timber "horses" *i i* are first formed. The "legs" are about 12 feet long, and 10 or 12 inches thick. These are partly sunk in the ground, and the upper ends are morticed into the "caps," which are 9 or 10 feet long. The horses are placed one on each side of the shaft, about 5 or 6 feet apart, the centre of the space between being in line with the span-beam of the whim.

Carriers are placed across the horses, and the bearings of the pulleys rest upon these. The pulleys are usually of different sizes. Where chain or hemp ropes are used for hauling, one may be about 4 feet and the other 2 feet, each being 4 inches wide. Wire rope is seldom used with a whim, but should it be used, the pulleys must be much larger. The total cost of such an arrangement will not much exceed £6. The contrivance just described is only suitable for a small shaft or for temporary purposes. A much larger and better pulley frame of iron will be described in a future chapter.

76. **Sinking Corves.**—The earth or rock, as it is broken *at the bottom* of the pit, is placed in "sinking corves" of

hazel wickerwork, as shown in fig. 68, or in iron corves (kibbles) more or less like that shown in fig. 64. They are made smaller at the top and bottom than in the centre, in order that the ascending and descending corves may push each other aside without upsetting as they pass and repass. The bows or handles must of course be well secured, by washers and cottar, or otherwise, in order that there may be no risk of their giving way. Square boxes of wood are sometimes used, but there is much greater risk of their coming into contact and upsetting. When an iron kibble is used a good deal of water may often be brought up with the earth, and the same kibble is available for drawing up water as it accumulates in the bottom.

Fig. 68—Corve of Basket-work.

77. Suspension of the Corves.—In some districts the corves are suspended by means of the spring-hook shown in fig. 69*a*, at other times the rope is knotted around the top of the bow, as in fig. 69*b*.

Fig. 69.

78. Striking Deals.—To diminish the risk of accident in the event of kibbles or corves striking against the covering of the pit, what are called "striking deals" may be used. These are pieces of wood placed as shown in the

upper part of fig. 70, which serve to guide the ascending corve through the opening at the top. The mode of fixing calls for no special remark.

79. Power of the Machines Described.—With the jack-roll, two men working 8 hours per day will raise, from a depth of 60 feet, from 80 to 100 kibbles, each containing two cwt. Including the weight of the kibble, and allowing for friction of the machine, the actual work will be about $1\frac{3}{4}$ million foot-lbs. With a one horse-gin, from 15 to 20 tons per eight hours may be raised from a depth of 40 fathoms, two horses will raise nearly double this quantity. Generally, a mule will do about two-thirds the work of a horse, a donkey one-fifth, and a man about one-seventh.

With the above data it will be easy to calculate the proper amount of work to be done when the machinery is in good order, under various conditions, and at various depths. Remembering that a gallon of water weighs 10 lbs., it will also be easy to calculate the quantity of water which may be raised in a given time.

80. Landing the Corves.—In some localities the corves are pulled aside as they reach the top of the pit, and their contents tipped into tubs or trollies. With a heavy corve, however, this is somewhat dangerous—a better plan is to use a spring hook and a spare corve. The corve on its arrival at the top is drawn aside, placed on a tub, and detached. The empty corve is immediately put in its place and sent down, [t]hat the delay is but trifling.

Fig. 70.

The best plan however, especially for heavy kibbles, is to have the top of the pit covered by a trap-door which opens to let out the ascending corve and then falls back by its own weight. A tram-road which extends from the tip to the edge of the pit is continued on the top of this trap-door. When the door falls, a trolly or tub, kept ready, is wheeled in under the kibble which is immediately lowered and upset. The tub is then withdrawn, the trap-door opened by a chain which is made to work by the machinery used in hauling, and the kibble at once descends. All this is effected in a very brief space of time, and without the least difficulty or danger.

81. Penthouses.—When men are working at the bottom of the shaft, and rock is being raised in the corves above their heads, there is a risk of accident and injury from falling stones. To protect them from this danger a temporary sloping roof of boards, called a penthouse, is sometimes placed over them while at work, as shown in fig. 70. Such a precaution should never be neglected when stuff is being raised over the men at work, and it is especially necessary in small shafts like that shown in the cut.

CHAPTER VIII.

OF DEAD WORK UNDERGROUND.

82. Gate-roads or Rolley-ways.—The pits or shafts being sunk to the required depth, and the seam of coal reached, the driving of a pair of galleries variously called "drifts," "headings," "levels," "waygates," "gate-roads," and "rolley-ways," commences. These are intended to form the main channels of communication between the different parts of the underground workings and the bottom of the shafts. They are cut as far as possible in the coal itself, and conforming to the general inclination of the seam, but not following the minor irregularities.

In some districts, however, where the seams are very much contorted, the main roads are driven in the rocks quite independently of the seams. These drifts are commenced from the bottom of the shaft, and in the best systems of working they are extended at once to the extremity of the royalty before any working faces are commenced.

The direction chosen for the main drifts will depend mainly upon the situation of the pits with respect to the boundaries of the royalty, but partly also upon the natural jointing or "cleat" of the coal. When there are two shafts, one main drift will proceed from each. Examples of these main drifts will be seen in fig. 71 at *a*, and at figs. 79 *a b*, 80*c*, etc. In some systems of working the main drifts are three in number, and they are known as the "rolley-way," the "high-water level," and the "low-water level."

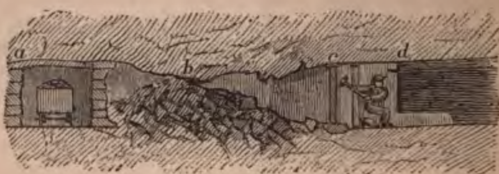

Fig. 71.

83. Pillars between Drifts.—A space of from 10 to 30 yards in width is usually left between the main drifts, more or less according to the greater or less depth from the surface, the condition of the "roof" and "thill," the tenderness of the coal seam, and other considerations. This mass is holed through at intervals from drift to drift, as may be required for ventilating the ends—say every 30 or 40 yards—the mass between being thereby converted into a series of pillars.

As each new holing is completed, a walling or trap-door partition is put in the one next, behind it, so compelling *the air to "course"* down one drift and up the other for

their whole length, as will be further described in the chapter on "Ventilation."

It is often possible, even when the seam is considerably inclined, to drive these main roads in such a direction as to result in a slope towards the shaft of about 1 in 130 to 1 in 200, which does not greatly differ from the Cornish miners practice of allowing half an inch per fathom fall in the direction of the load.

84. Shaft-Pillars.—The first portion of the main road is cut only a few feet wide, so as to leave as much as possible of the seam undisturbed around the shaft to form a "shaft-pillar." The shaft-pillar will be from 40 to 80 yards square, according to the depth from surface, and in very deep mines may be much more than this.

Farther on the drifts are enlarged into galleries of 10 feet, 12 feet, or even more, in width, and from 6 to 9 feet high. It will generally happen that one of the drifts will be at a somewhat lower level than the other, this will form the "drain" or "watergate," and will serve to convey the drainage of the whole mine to the sump, from whence it will be raised to the surface by the pumping engine.

85. Packwalls.—A wall of coal is usually left between the main drifts, as already mentioned, but occasionally this is removed and the drifts are kept open by walls of debris known as "packwalls," as shown in fig. 72. Frequently, however, the debris is too weak or rotten to be used for this purpose.

86. Walling of the Drifts.—Whenever the main drifts are not through the coal itself, and occasionally even when this is the case, some special support of timber or otherwise is necessary to keep them open. When the debris is not strong enough to be used as a packwall, walling of masonry is resorted to, especially where good building stone or brick is available. An excellent mode of supporting main drifts at crossings, or other important places, is by means of an arch of brick or stone resting upon an inverted arch below. Except in Staffordshire, the seams

of coal are rarely as thick as the required height of the main drifts, so that it is usually necessary to cut away part of the overlying or underlying rocks—the "roof" or the "thill"—sometimes one, sometimes the other, as circumstances may indicate. In the rare cases when the seam is thicker than the height of the drift, as in the case of the great five fathom seam in South Staffordshire, part of the coal is left to form the roof of the drift.

87. Cost of Arching.—The cost per fathom of arching a drift with bricks, when the bricks are made on the spot, is somewhat as follows—say for a drift 8 ft. wide and 7 ft. high (the cost of a smaller or lower level will be proportionately less); the walling and arch to be "one brick thick," laid in lime mortar, and well rammed behind with clay:—

	£	s.	d.
1500 bricks at 20s. per thousand, - - -	1	10	0
Lime, 2 cwt. at 9d., - - - - - -	0	1	6
Sand, 6 cwt. at 2d., - - - - - -	0	1	0
Labour in laying bricks and pugging behind, -	0	10	0
	£2	2	6

If the floor be formed by an inverted arch, the cost will be about one-third more. Occasionally, arching of "half a brick" thick will suffice, when the cost will be about two-fifths less. The above calculation includes nothing for the wooden "mould board" or "centering," which is used again and again for the whole length of the drift. As a rule, arching with stone will be from one-third to one-half more expensive than brick arching.

88. Mode of Arching a Drift.—The ground is first cut away somewhat larger than the intended drift. For permanent work the best mode is to build up the sides to the commencement of the turn of the arch, filling in behind as the work progresses. A wooden frame or centering, the shape of the intended arch, is then brought forward, about the length of a brick, and the arch constructed upon it and filled in above by gentle ramming. In half an hour or so, the centering may be advanced, and another row of

brick placed; so proceeding and following the advance of the excavators until the whole drift is completed.

89. Timbering of Drifts.—In many cases, where main drifts require support, some system of timbering is resorted to. A very excellent mode of timbering drifts, when they are not too wide, or when the roof is tolerably strong, is that shown in fig. 63. It is composed of strong "pairs," "frames," or "sets," *a b c*, which are backed up by "backing deals" or "laths," as at *d e*. The bottom portions of the sets at *c*, often called "stretchers," serve as sleepers upon which the tram-rails may be conveniently fastened.

90. Cost of Main Levels.—This will greatly vary under different conditions. The following actual examples which came under the notice of the writer will give some idea of cost:—

No. 1. South Wales, 1873. 6 ft. high and 6 ft. wide; 3 ft. in coal and 3 ft. in soft shale or clift forming the roof of the drift. Price paid 12s. 6d. per yard; 3s. 1½d. per ton of coal got out in driving, in a condition fit for sale, and 3s. for putting in each "pair" or "set" of timber.

No. 2. South Staffordshire, 1872. Heading, 9 ft. wide, 6 ft. 6 in. high; coal, 4 ft.; underclay, 1 ft.; the remaining 1 ft. 6 in. in shale forming the roof. Price paid, 28s. per fathom, and 2s. 6d. per ton of coal.

No. 3. North of England, 1873. Drift 7 ft. high 9 ft. wide; seam of coal 2 ft. 6 in.; roof of soft sandy shale for the remaining 4 ft. 6 in., no timbering required; 32s. per fathom.

91. Trial Borings against old Wastes.—We have, in Chap. IV., described in detail the mode of carrying out vertical trial borings for the purpose of proving the strata before sinking. Sometimes it is necessary to bore horizontally in advance of the workings, especially when main headings are being driven from new shafts towards old wastes of adjoining collieries filled with water. A very light form of rod is sufficient for this purpose, and the chisel should not exceed $1\frac{1}{4}''$ to $1\frac{1}{2}''$ diameter. A modification of the diamond drill, which penetrates by rotation instead of by percussion, is probably the best possible mode of carrying out such works.

The safest way to prove an old waste is to commence a pair of narrow drifts, only just wide enough to work in, and not more than 5 yards apart, as shown in fig. 72 at *c c*, *d d*, and communicating with each other at intervals by cross-drifts *e e*. A trial borehole should be kept in advance of each as at *a a*, and at every 10 yards or so,

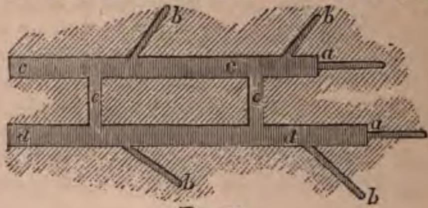

Fig. 72.

flankholes *b b* should be bored. If the wastes are known to be large, and especially at a great depth from the surface, the work should be carried out with the utmost possible precaution. The holes should be deeper, *i.e.*, further in advance, in proportion to the depth from surface and consequent pressure to be encountered. The table given in the next paragraph shows the proper distances in advance for different depths—a moderately hard seam being supposed, and a hole of 1½ inches diameter. In hard ground the borings may be much shorter, and in tender ground the distances given are scarcely sufficient.

92. Quantity of Water from Boreholes.—This is very considerable at times, especially when the depth from surface is great. Thus, at the Towneley Colliery, the "five quarter seam," a hole 25 ft. long (deep) and 1½ inches diameter, under a pressure of only 66 ft. discharged 125 gallons per minute. Another hole in the Towneley seam at the same colliery, 11 ft. long 1½ diameter, yielded 140 gallons per minute. The annexed table gives the safe lengths of boreholes when in moderate ground.

Depth from surface in fathoms,	5	10	15	20	25	30	50	75	100
Length of hole in advance, in yds.,	6	7	8	9	10	11	15	20	25

93. Security of the Explorers.—When the waste is reached and the water begins to flow, it sometimes does so with dangerous rapidity. It may be necessary to plug the holes for a time, until the tools and appliances are cleared away and the pumping arrangements are completed. For this purpose, long taper plugs of fir wood must always be kept in readiness when such works are going on. These should be from 4 to 6 ft. long, gently tapered, and hooped with iron at the head to prevent them from splitting when they are driven into the hole. If the water should issue with violence it may be necessary to fasten a cross-piece to the plug near its head, which may be held by two men, and the plug thus forced into the hole so as to stop the flow until arrangements for carrying away the water are completed.

94. Dams.—Sometimes the waste having been discovered is simply dammed up, but it will always be much safer to lay it dry by pumping. It is, however, frequently necessary to construct dams underground to keep back flows of water, which would need a constant expenditure of pumping power. We will, therefore, describe the construction of some of the dams in common use.

95. The Frame Dam.—Fig. 73 plan, and fig. 74 elevation, is constructed as follows:—The space for its reception is first sheared back by picks or wedges to the required form, *without blasting*, which would be liable to shake the rock and make the strata around the dam leaky. For the same reason it is important to select a position in which the rocks are undisturbed by faults, slips, or other irregularities. A number of balks of fir wood are then carefully dressed to a square form and tapering towards one end, as shown in the figure. The amount of taper will of course depend upon the radius of the sweep of the dam. The pieces may be dressed and fitted together at surface into the form of the required dam underground, and numbered before being taken down. According to the pressure to be resisted and the area of the dam, the pieces will be required longer or shorter, but a dam of

the dimensions given in the figure will stand almost any pressure.

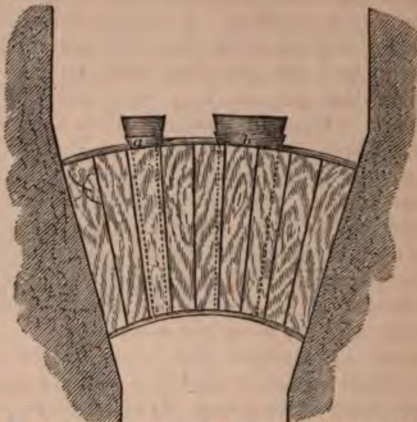

Fig. 73.—FRAME DAM, Plan. *Scale* ¼ in. = 1 ft.

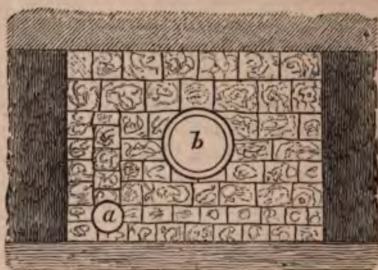

Fig. 74.—FRAME DAM, Elevation. *Scale* ¼ in. = 1 ft.

While the dam is being put in, it will be necessary to insert several strong metal tubes, and to fit the tapered beams to the outside of these. Near the bottom is one—*a*, 5″ or 6″ diameter, large enough to allow the feeder of water to pass through, the second *b*, about 18″ diameter,

or large enough for the ingress and egress of the workman, and a third about 1″ diameter is sometimes placed near the top to allow of the escape of gas.

96. Fixing the Dam in Place.—All the materials being ready, the workmen build up the dam in its place; first covering its seat and walls with a thick layer of tarred flannel. The feeder of water is then conveyed by wooden pipes, "boxes," or "launders," to the inner side of the lower pipe, through which it flows, leaving the whole back end of the dam dry. Wedges of fir 12″ long, 2″ or 3″ wide, and 1″ thick at the head, are then forcibly driven in from the back, between the timbers, commencing at the bottom and working upwards until no more can be driven in. A plug is then driven into the lower pipe, and the men come out through the large one drawing a plug in after them there also.

The dam is constructed of thoroughly dry timber, and the swelling of this, as it becomes wet, together with the wedging behind, generally suffices to make it perfectly tight. Sometimes, however, the pressure is so great that the whole dam is forced forward, and to provide for this the seat is continued forward, as shown in the plan.

97. Dams of Masonry.—Sometimes dams are constructed of brick or stone, and built up in much the same form as that just described. For slight purposes, dams may be built up of a double series of balks of timber placed crosswise, the ends resting in a recess cut for their reception, and the space between puddled in with clay. Such a construction, however, is only suitable when the pressure of water is not great.

CHAPTER IX.

EXPLOITATION, OR MODES OF WINNING THE COAL.

98. The main headings being opened up, the process of "winning" the coal may be commenced. This is done in many different ways, the chief of which are known as "post and stall," "square work," and "long-wall," winnings. These we shall now briefly describe.

99. Post and Stall Work.—This is the most common mode in the Newcastle coal-field, and was formerly the only method adopted in that district. It may be described as a series of parallel levels or "bords" separated from each other by thick masses of the coal, which are left standing for a time to support the roof, as shown in fig. 75. These again are crossed by similar drifts parallel to each other, and usually at right angles to the first, so that the coal seam is divided into a series of rectangular pillars. Formerly these pillars were left only a few yards thick, when they soon became so much crushed by the great weight of the rocks above as to be almost useless for support, and quite worthless for fuel when subsequently extracted or "robbed." They are now often left in deep collieries as much as 30 yards by 40 yards, or even of still greater thickness, only a small proportion of the coal being removed in the first instance, but the rest being won as soon as possible afterwards.

100. Robbing the Pillars.—When these different sets of drifts have been completed in any one part of the mine, the next operation is to "rob" the pillars by cutting them away successively, somewhat as shown in fig. 76. The roof is supported by props of wood or metal while these pillars are being removed, and these props are taken out by the men last of all, as they work back towards the "air-courses," or towards the shaft. Of course this is a work of danger, as the roof is liable to fall upon and crush the men. The danger is often increased by their own

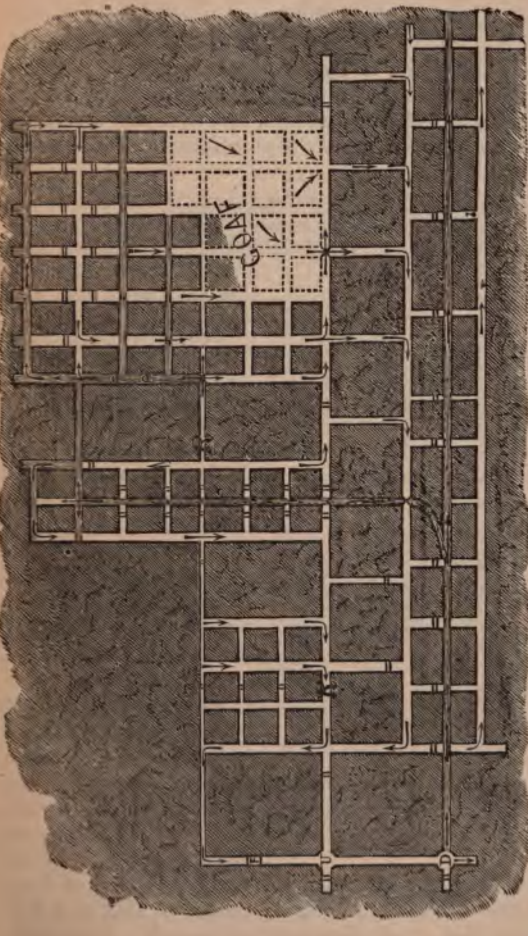

Fig. 75.—Post and Stall Work. =X= are crossings; ‖, partitions. The arrows show direction of currents. R, R, are regulators; D, D, doors; D, is the downcast, U the upcast shaft. The tram-roads are shaded.

recklessness, in working with the props too far apart, to save themselves trouble in fixing. In most post and stall workings a considerable proportion of the props are lost by the *roof* falling in, or by the *thill* "creeping" up before they can be got out. Many other modifications of post and stall work are in existence, but that just described will serve to indicate the chief peculiarities of this mode of working.

Fig. 76.—Showing Mode of Removing Pillars.

101. Square Work.—The mode known as "square work" is shown in fig. 77, which, with the accompanying description, is taken from Mr. Smyth's valuable work on *Coal and Coal Mining*. It is a dangerous and wasteful mode, and but little used except in working the famous Dudley "thick" or "10 yards" seam.

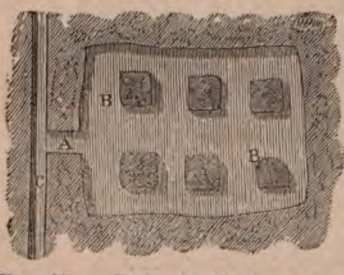

Fig. 77.—Diagram Illustrating "Square Work." A, bolt hole; BB, pillars; C, airway from shaft.

"The shafts are sunk to the bottom of the seam, and a mainway, the 'gate-road,' is carried forward in the lower coals, ventilated by means of a separate air-head or drift of very small dimensions opened in the coal also, at a few feet on one side of or above the gate-road. From this

latter the main workings, called 'sides of work,' are opened in the form of a square or parallelogram 50 yards in the side or more, and shut off by a rib of coal 7 or 8 yards thick at the least, from all other workings, except at the entrance by a narrow 'bolt-hole.'"

Driving out in the lower coals and gradually rising to the higher ones, the colliers open stalls of 6 to 8 or 10 yards wide, forward and across, so as to leave square pillars, generally 9 or 10 yards in the side, and whenever the unsoundness of coal or roof appears to require it, sparing additional supports of coal in "men-of-war," 3 or 4 yards square.

The men get at the upper divisions of the seam by standing on the slack and coal already cut, or on light scaffolding. No ordinary timbering can be used to support so high a roof, nor can the eye in these vast and murky chambers easily detect when special danger threatens overhead; but the sense of hearing comes valuably into play, and a sharp ear often catches the preliminary crackling which indicates the approach of a fall. Nevertheless, the work is the most dangerous in which the collier can be engaged; and no mode of getting this coal with a less serious destruction of life has been devised, except that of working it in two "lifts," by the long-wall method, which, in spite of much opposition, appears at a few works to have stood successfully the result of many years' practice.

The pillars in the "square work" are often, in conclusion, thinned to a smaller size, and when at length the roof begins to break in, the side of work is abandoned, a dam is put into the bolt-hole, and thus the air is excluded from the heaps of waste small coal, and the crush prevented by the ribs from extending to other parts of the pit.

"It scarcely needs to be added, that although after the first working, operations may be set on foot for getting the ribs and pillars, much of the coal is so crushed or 'frenzied' as to be of little use. The waste of some thousands of

tons of coal per acre, and the great sacrifice of human life in the process, lead one to contemplate with no pride or satisfaction our mid-English working of the finest seam of coal in Europe." *

102. Long-wall Working.—The long-wall mode is sometimes carried out by commencing at once near the shaft-pillar and working away the whole of the coal, leaving only "goaf" or "gob" behind, and supporting the necessary roads through it by masonry or packwalls. This mode is shown in the upper part of fig. 78.

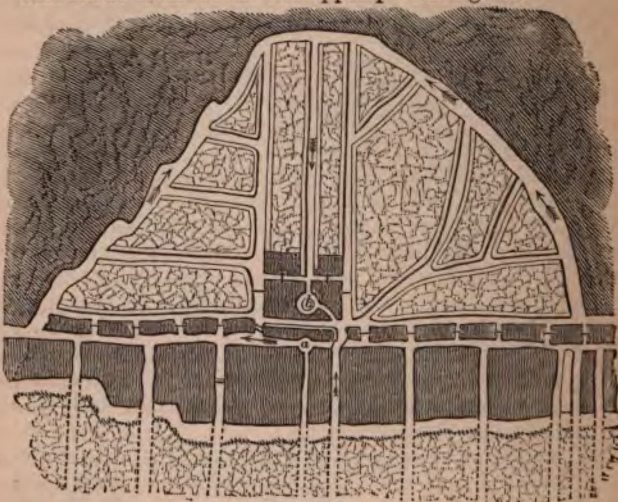

Fig 78.

At other times the roads are at once driven out to the boundary of the royalty, and the coal worked back in the long "face" or "wall," as shown in the lower part of the fig. The various modifications of the long-wall method are much approved by modern colliery engineers, and adopted in many of the largest and deepest collieries in

* Smyth's *Coal and Coal Mining*, pages 137-138.

the North of England and S. Wales. A cross-section of long-wall working is given in fig. 71, which shows the process of "holing" the coal. *

103. Goaf.—The part from which the coal has been wholly removed, is called the "goaf" or "gob," and this is of course in communication, more or less direct, with the parts where the men are still working. It soon becomes, in great part, filled up by the deposition of rubbish, and especially by the rising of the thill and the sinking of the roof, but enough space is left to allow of very dangerous accumulations of inflammable gas or fire-damp, and this has been the source of many of the most disastrous explosions. It is to guard against such explosions that "safety-lamps" have been introduced. These will be described in the chapter on Ventilation.

104. Production of Round Coal and Slack.—The coal, by whatever method it is worked, is always got out as much as possible in blocks of fair size, often called "round coal." A "hole" or channel is cut along the face in the lower part of the seam by means of a long double-headed pick, called a holing-pick, and the coal is broken down by wedges, or, when tender, falls by its own weight. Except in the case of the hard anthracitic coals of South Wales, blasting is seldom resorted to, not only on account of the great danger from explosion of fire-damp, but also because the concussions would too much fracture the coal, and produce too large a proportion of "slack." This slack often, even now, amounts to one-third of the whole. It was formerly worthless, but is now frequently worked up into coke or into patent fuel. Of course, in sinking the shaft, in the first instance, blasting is very generally required. The laborious process of holing is shown in fig. 71.

Several machines have been invented to perform this work, some of which work remarkably well, and will, no doubt, make their way in time.

Beds of iron ore which occur interstratified with the coal measures are worked much in the same way as the coal itself.

* From Smyth's *Coal and Coal Mining*, p. 139.

CHAPTER X.

UNDERGROUND HAULAGE.

105. Distance of main Rolley-ways from Working faces.—In well arranged collieries the distance of the working faces from the main roads or rolley-ways rarely exceeds 30 or 40 yards, and is often much less. A considerable economy results from this practice, since the rolley-ways are usually laid with tram-rails or tram-plates, upon which tram-waggons or tubs are kept running, while the communications from the working faces are mostly narrow and irregular, necessitating the use of "sleds," wheelbarrows, or other expensive modes of conveyance. It is important, however, so to arrange the general plan of working, that no excess of rolley-ways may be required since these are among the most expensive of underground works. Good plans of working are shown in figs. 75 and 78.

106. Inclination of Rolley-ways.—Where the tubs have to be pulled by manual labour, a downward inclination of $\frac{1}{2}$ to $\frac{3}{4}$ inches per fathom will be found most economical; with less than this the labour of haulage of the full tubs will be too great, and with more it will be difficult to bring back the empty tubs. Where the inclination is considerably greater than that just stated, it will be necessary to employ horses to bring back the empties, or else to arrange an endless rope working round a drum so that the weight of the descending filled tubs may aid in pulling back the empty ones. The drum may be moved by horse, water, or steam power; but where the inclination of the road is great, the weight of the loaded tubs themselves will be more than sufficient, and it may be necessary to regulate their descent by powerful brakes.

107. Tram-roads.—Various forms of rail are used in

different districts, some of which are shown in fig. 79. The "bridge rail," shown in full-sized section in fig. 80, is very useful and durable when made of good iron. Its weight is about 14 lbs. per lineal yard. These bridge rails are fastened by means of flat-headed 2″ nails to wooden sleepers placed longitudinally or transversely. Fir battens 7″ wide and 2″ thick, are well suited for such work, and form a very durable and economical road when well laid and packed underneath. The whole cost of such a tram-road, 3 ft. wide, will be from 3s. to 4s. 6d. per yard, according to the price of iron and timber. The rails are laid to many different guages, but 36″ apart will be found a very convenient distance for most purposes.

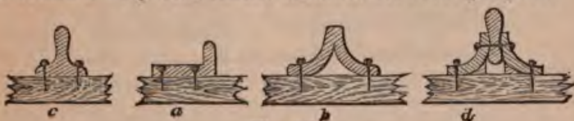

Fig. 79.

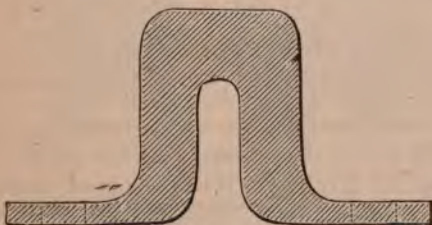

Fig. 80.—Light Bridge Rail, Full-sized Section.

108. Tubs.—Convenient forms of tubs for underground haulage are shown in figs. 81, 82, and these, if made of $1\frac{1}{2}''$ deal or $\frac{3}{4}''$ oak plank, bound with iron $\frac{1}{8}$ of an inch thick, and with light wheels and axles, need not weigh more than 3 cwt., and will hold from 8 to 10 cwt. of coal. The cost should not exceed £4 or £5.

Some tubs are made with a revolving swivel frame placed between the bottom frame *a* and the box *b*, some-

what like the "under-carriage" of a four-wheeled chaise. This adds from 25s. to 40s. to the cost, but enables the tubs to be readily "tipped" in any direction. Where the roads are nearly straight, the wheels may be fixed to the axles, but where there are numerous curves it will be better to leave them loose and give them ½″ or more "play" upon them. In such cases, also, the wheels must be placed as close as possible together.

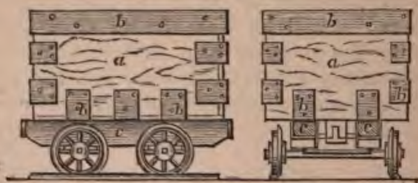

Fig. 81.—Colliery Tub. *Scale* 1 in. = 4 ft.

Fig. 82.—Colliery Tub. *Scale* 1 in. = 4 ft.

109. Cost of Hauling.—When the road is good, the level high, and the ventilation sufficient, the cost of hauling or "putting" underground will not be very much greater than at surface, say by manual labour, from 3d. to 4d. per ton for 300 or 400 yards. With bad roads or low drifts the cost may be two or three times this amount, and in some cases even five times as much.

In many cases, where the distances are considerable, the hauling is done by donkeys, ponies, or horses, when the cost will usually be less than half, if a small boy be employed to drive, and the horse be kept fully at work The cost may often be still further largely reduced by

using a steam engine, if the quantity to be moved is large.

110. Inclined Planes.—When the coal has to be brought up-hill, the best mode will be to use a wire rope attached to the tubs, and passed over a winding drum or one of Fowler's "clip pulleys." If the road be tolerably steep, the empty tubs, on going down, will take up the slack of the rope, and, to some extent, assist in raising the next full tub. If the road be horizontal this result will not be attained, and it will be necessary to use an endless rope passing round a sheave at top and bottom, or else to employ a smaller "tail rope" of $\frac{3}{4}''$ circumference, so as to haul the empties down again. The endless rope method may also be used on level roads where they are sufficiently straight.

One of the most economically worked inclined planes in the United Kingdom is at Shire-oak Colliery in Nottinghamshire. It is 800 yards long, with a gradient of 1 in 50. A small engine with two 12″ cylinders of 24″ stroke, causes a Fowler's clip-drum, 4 ft. diameter, to make 80 revolutions per minute, by which a train of 25 tubs is brought up at a speed of 8 to 10 miles per hour. The average cost is about 1d. per ton, including all materials and labour.

CHAPTER XI.

HAULAGE IN SHAFTS.

111. Windlass, etc.—In small collieries, the windlass or gin, already described (Chap. VII.), may suffice for raising the coal to surface, in which case it is brought from the working faces in wheel-barrows or baskets, and raised in corves like fig. 68, or kibbles like fig. 64, or some similar contrivance. In large works, some more powerful arrangement is necessary.

112. Water Wheels.—It is not often that water wheels are arranged for hauling purposes, although in some instances they have been used with excellent effect. The only peculiarity is the application of suitable gear for reversing or stopping the motion. There is no great difficulty in this; but the inconvenience is sufficient to prevent their extended use for such a purpose in shallow mines, and in deep mines a sufficiency of water power is rarely available, and what there is may be often more advantageously used for pumping. We shall, therefore, reserve our remarks upon water wheels for the chapter on pumping machinery.

113. Water-balance.—In many of the open works on the northern side of the great coal basin of South Wales, water-balance machines are largely used for winding purposes, and for mines of not more than 100 fathoms deep; in a district affording a good supply of water, and free drainage by means of adits, they may be highly recommended. Sometimes they are used when there is no drainage, the water being pumped up from the bottom by an engine, but this is not to be recommended. In some cases the machines are placed at different levels, so that the same water is used five or six times, over as many successive lifts. The tram, containing from 12 to 20 cwt., is placed in a cage over an empty water bucket, and the empty tram on a similar bucket at the top. Water is then made to flow into the upper bucket until its weight is great enough to cause it to descend, so raising the filled tram. On the arrival of the full bucket at the bottom of its fall, a self-acting valve opens and the water is discharged, so allowing the process to be repeated. The buckets are made of $\frac{1}{2}''$ boiler plate, circular in form, and some hold more than 2 tons of water. The landing chain is balanced by a chain which hangs below each bucket, and guide chains are used to keep the buckets from striking each other when the shafts are not divided. A speed of 300 to 400 feet per minute is easily attained by this machine, and the total cost of raising stuff is about $1\frac{1}{2}$d.

per ton per 50 fathoms. For great depths the weight of the necessary machinery becomes so great that the economy is reduced or disappears. Somewhat similar machines are in use in some of the iron mines of Cumberland and elsewhere.

114. Hauling in Cages.—In the best mode of working extensive collieries, the tubs, as they reach the shaft, are run directly into "chairs" or "cages" of one or more stages, as shown in fig. 83. These are made of iron or steel, as light as possible, consistently with sufficient strength.

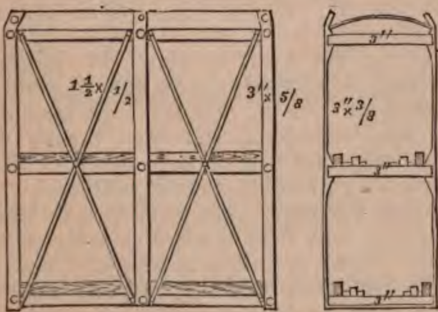

Fig. 83. *Scale*, 6 ft. = 1 in.

The general form is evident from the sketch, but we have not sufficient space at disposal to give details. The weight will be from 5 or 6 cwt., for a single tub, to one ton or more for four tubs. Cages holding eight tubs are used in some parts of Belgium weighing little over a ton.

115. Guides.—The cages work between guides of fir wood nailed to *buntons*, which are cross-pieces fixed across the pit at intervals. When the pit is vertical, as is usually the case, these need not be more than 4″ × 3″, and the total cost not more than 12s. to 15s. per fathom, including fixings. Sometimes iron guides are used, when the cost is considerably more.

116. Speed of Winding.—The use of guides has enabled the colliery proprietors largely to increase the output from each pit by increasing the speed of winding. In seven of the chief pits of the United Kingdom, the average rate is no less than 1400 ft. per minute, and the maximum rate at Dukinfield 1600 ft. This is nearly five times as rapid as the usual rate in the tin mines of Cornwall. In the Navigation Pit at Aberdare, the weight raised, of cage, coal, rope, etc., is about 9 tons.

117. Landing the Tubs.—The cage is lifted a little above the level of the bank, and then allowed to fall back upon the "keeps." This is a kind of skeleton platform counterbalanced by levers, which are raised by the ascending cage, and fall back by their own weight. The tubs are then rapidly run out by men in waiting, other empty tubs are run in, and the cage rises while the "keeps" are withdrawn, and then rapidly descends. When the cage has two or more decks, much time is saved by having a landing stage at each level.

118. Shaft Partings.—The winding shaft often serves as a pumping shaft also, in which case that portion containing the column of pumps is separated from those in which the cages run, as in fig. 84, and these are also sometimes separated from each other.

119. Safety Catch.—Sometimes the cages are fitted with safety catches which are intended to prevent the fall of the cage in case of the ropes breaking. One very convenient form of this contrivance consists of a strong spring which serves as the connection between the rope and the cage. The weight of the loaded cage keeps this spring bent, but if the rope should break it is at once relaxed, and, by its recoil, sets free some strong teeth, which immediately force themselves into the shaft railway or guides, and so keep the cage from falling. But all such contrivances are liable to get out of order unless constantly watched; and, as it is difficult to induce men to prepare for a danger which seems very remote, many practical miners prefer to do without all such appliances, and to trust entirely

to the perfection of the rope, which is constantly under the inspection of the manager or his appointed agent.

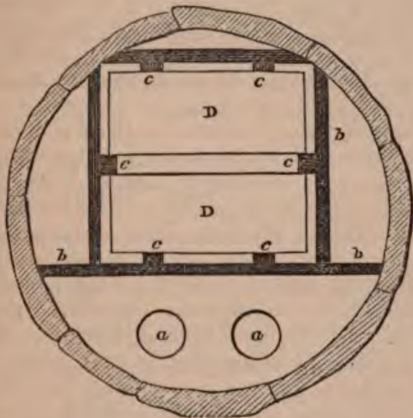

Fig. 84.—*a*, *a*, Pumps; *b*, *o*, partings; *c*, *c*, guides; *d*, *d*, cages.

120. Ropes.—For shallow pits chain or hemp rope may be used with great propriety, because of the facility with which it may be coiled round small barrels or drums, but for considerable depths, and especially where great weights have to be lifted, the use of wire rope in some form is both safer and much more economical—and is, indeed, now almost universally used. Wire ropes may be either round or flat, of iron-wire or steel. For round iron-wire ropes drums of less than 12 feet should never be used; for flat ropes and ropes of steel-wire somewhat smaller drums may be used, but are not to be recommended in general.

121. Strength of Ropes and Chains.—The following tables of the equivalent working strengths of chain, hemp rope, iron-wire rope, and steel-wire rope, will be useful to

the young student. They all refer to material of best quality.*

TABLE 1.—WEIGHT AND STRENGTH OF CHAINS.

Diameter of Iron, ...	$\frac{5}{16}$ in.,	$\frac{11}{16}$ in.,	$\frac{15}{16}$ in.
Weight per Fathom, ...	$5\frac{1}{2}$ lbs.,	28 lbs.,	49 lbs.
Working Load, ...	24 cwt.,	54 cwt.,	120 cwt.

TABLE 2.—WEIGHT AND STRENGTH OF GOOD HEMP ROPE.

Circumference, ...	$5\frac{1}{2}$ in.,	8 in.,	12 in.
Weight per Fathom, ...	7 lbs.,	16 lbs.,	36 lbs.
Working Load while new,	24 cwt.,	54 cwt.,	120 cwt.
Breaking Strain, ...	8 tons,	18 tons,	40 tons.

TABLE 3.—WEIGHT AND STRENGTH OF IRON-WIRE ROPE.

Circumference, ...	$2\frac{1}{8}$ in.,	$3\frac{3}{8}$ in.,	$4\frac{5}{8}$ in.
Weight per Fathom, ...	4 lbs.,	9 lbs.,	20 lbs.
Working Load, ...	24 cwt.,	54 cwt.,	120 cwt.
Breaking Strain, ...	8 tons,	18 tons,	40 tons.

TABLE 4.—WEIGHT AND STRENGTH OF STEEL-WIRE ROPE.

Circumference, ...	$1\frac{3}{4}$ in.,	$2\frac{1}{2}$ in.,	$3\frac{3}{4}$ in.
Weight per Fathom, ...	$2\frac{1}{2}$ lbs.,	$5\frac{1}{2}$ lbs.,	12 lbs.
Working Load, ...	24 cwt.,	54 cwt.,	120 cwt.
Breaking Strain, ...	8 tons,	18 tons,	40 tons.

122. Safe Working Loads.—As shown in the tables a very large allowance of strength is made for safe working, the working load being taken at less than one-sixth of the ultimate strength. With hemp rope and chains a still greater allowance should be made on account of the imperfection of material and workmanship to which they are specially liable. A large allowance must be made, too, for the strain due to the extra pull in starting. Sometimes this is partly relieved by mounting the bearings of the winding pulley or drum upon springs, but even when this is done the extra strain will be very considerable.

* Very complete tables of equivalent strengths are given in Molesworth's *Pocket-book of Engineering Formulæ*.

123. Weight of Winding Gear.—The weight of the chain or rope itself must be taken into account when any considerable length is used, and this too will be much greater with chain or hemp rope than with wire rope. Indeed, for deep pits the use of chain would be forbidden by this consideration alone, as a chain of 300 fathoms long, capable of working with a load of 24 cwt., would itself weigh nearly one ton, while a steel-wire rope of the same strength would weigh only 750 lbs.

At the Navigation Pit, Aberdare, the total weight of cage, load, and wire rope, is no less than 9 tons, the rope, of round steel wire 2″ diameter, alone weighing about a ton. The depth is 360 yards. More than 500 tons of coal are often drawn from this pit in a single day, the cage being made to carry two tubs at a time each holding more than one ton.

To relieve the winding-engine, and to enable it to overcome the weight of a long length of rope, the size of the drum is made to vary, or the speed of winding at first is reduced. This may be effected either by using a conical winding drum, or by using a flat rope and causing it to wind upon itself.

124. Over-winding.—To prevent accidents from over-winding, which are sometimes very disastrous, it is usual to attach some visible mark to the rope at a known distance from the cage. The banksman, keeping his eye upon this, knows as soon as it comes in sight that he must prepare to check the ascent of the cage by stopping the engine or putting on the brake. Sometimes the rope itself is made to ring a bell as it rises to a given point, and frequently there is in the engine-house a sort of reduced model of the shaft showing the exact position of the cage at any given moment. Several ingenious forms of indicator have also been devised, but we cannot afford space to describe them.

125. Walker's Patent Hook.—When all possible care is taken, accidents from over-winding may still sometimes

happen. To render such accidents harmless in the future, Mr. Walker of Cleveland, has invented the self-detaching hook shown in fig. 85. When this is used, should the kibble, which hangs to the ring B, be carelessly raised too high, the arms E E are drawn up through the ring K, which is fixed firmly to a beam of wood M M across the shaft, the jaws F F are opened, the rope L is liberated, the weight is taken up by the catches G G, and the rope goes over the pulley without injury.

Fig. 85.

126. Cost of Winding.—With a sufficiently powerful engine, a good pair of cages, tight tubs, guides in good order, an intelligent engine-man, and perfect arrangements for filling and emptying above and below, so that there may be no loss of time, the cost of winding from deep pits will not exceed ¼d. per 100 fathoms.

127. Hauling from Deep Mines.—Many forms of engine are used for hauling coal from deep mines, the principal being Boulton & Watt's double-acting rotatory beam engine, and the horizontal engine. The economical and convenient working of all the different forms depends mainly upon their general proportion and construction; but, on the whole, it may be said that beam engines are the more durable, and horizontal engines the more convenient.

128. Horizontal Engines.—A cheap and durable *horizontal engine*, made by Messrs. Tangye of Birmingham, is

shown in fig. 86. These engines are made in all sizes with or without special expansion valves, and winding gear is very readily attached to them. A pair of large-sized engines of this class, working cranks at right angles on the same shaft, with a winding-drum between, and fitted with expansion valves, friction brakes, and reversing gear, working with steam of 60 lbs. pressure, abundant

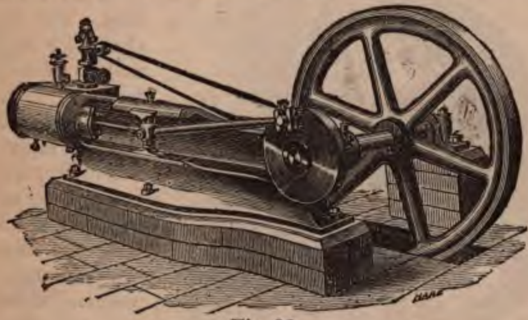

Fig. 86.

boiler power, and a good condenser, leave nothing to be desired either for economy or efficiency. Such an arrangement is shown in fig. 87. A A are the cylinders, B B the cast-iron sides of the winding-drum, C is the crank shaft, D the crank plate, E E are the cross-head guides, *f* is the friction brake strap, working on a double-flanged seat cast in the solid, *g* is the reversing handle, H H is the bed-plate of cast-iron, which is firmly bolted down to a masonry foundation in the usual manner. Messrs. Pollok and M'Nab of Hyde, near Manchester, are making very convenient double-cylindered horizontal engines. In one of these engines lately completed, the cylinders are 16 in. diameter, with a stroke of 3 ft., fitted with pistons made on the coil-spring principle, and with piston-rods extending through the back cylinder covers, the latter being made of best crucible steel 3 in. in diameter. The slide-bars are made to rest with their whole surface on the bed-plate, due attention being paid to the easy

oiling of the slides, and for collecting the grit at the other end.

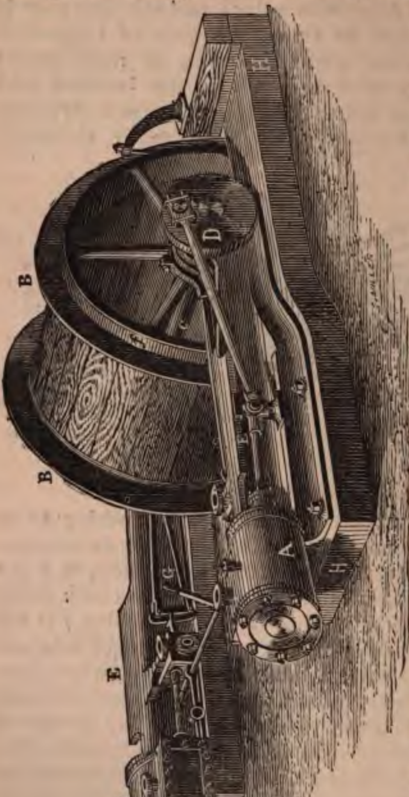

Fig. 87.

Extra length and bearing surface has been given to the slide-blocks, and the cross-head ends are forked with double bearings. The drum-shaft is 9 in. diameter with 7-in. necks of wrought iron, and has a keyway sunk the whole length of its surface, in order to fix at pleasure the drum-sides at any distance asunder. The latter are made in halves, likewise of heavy construction. The pedestals carrying the drum-shaft are inclined, so as to throw the central thrust on to the solid part. The cranks are set at right angles to each other, being fitted with Bessemer steel crank pins. These engines are provided with the curved

slot-link reversing motion, working with double eccentrics and single-slide valve. The valve-spindles are carried by a bracket between the ends of the slide-bars, forming one of the slide-pillars for the same, the valve-chests being cast with the cylinders. For quick starting and stopping a wedge stop-valve is used, and the cross-shaft connecting the two link motions is arranged underneath the floor-line, so as not to be in the way of the engineer, within whose easy reach and control the foot-lever for brake and the stop-valve handle are brought. The brake-strap is arranged to one drum-side, for which purpose the latter has a double-flanged seat cast on, and subsequently turned, to ensure a perfect surface for the brake-strap. Occasionally, the same engine is made to do duty in both pumping and hauling, when a somewhat different arrangement is necessary.

129. Pulley Frames.—The rope passes from the winding-drum over a pulley fixed at the top of a pulley frame of wood or iron. If the winding-rope be of iron-wire, the "sheave" should not be less than 12 ft. diameter. The frames are from 40 to 80 ft. high. If of wood, they are made of balks of American or pitch pine as straight as possible, and from 14″ to 18″ square, well stayed against the strain with stays of somewhat smaller section. In the best collieries frames of iron are now often used, and the cost is not greatly in excess of the wood frames. An iron frame of good construction, 80 ft. high, to take a load of 2½ tons, should not exceed 10 tons in weight.

CHAPTER XII.

PUMPING MACHINERY.

130. Accumulations of Water.—There are few situations where workings can be carried to any considerable depth below the surface without interruption from the

accumulation of water. The surrounding rocks always contain more or less of water, which occupies their joints, fissures, or cavities. This rapidly accumulates wherever the excavations are deepest, and must be removed in order that the works may be carried on. In some few of the older and less extensive collieries the water was got rid of by adits or water-levels, but this can seldom be done in modern coal mines of large extent.

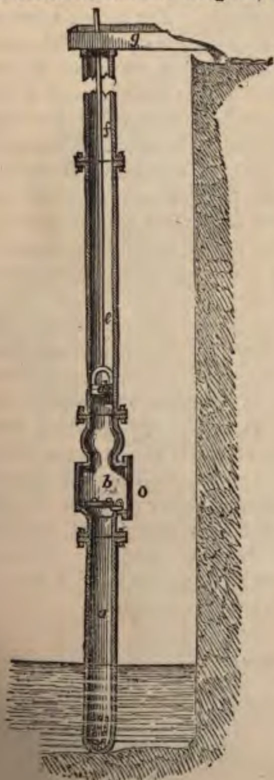

Fig. 88.

131. Pumps and Pit Work.—In trial shafts or pit sinkings, or in a district already partially drained by surrounding mines, the water may be raised in tubs by means of the windlass or horse-gin, described in Chapter VII. As the depth and quantity of water are increased, however, this mode is found quite inadequate, and some form of pump is necessary, which may be either a "lifting pump" ("bucket set" or "sinking set"), or a force pump ("plunger set" or "ram").

132. Bucket Set.—This is shown in fig. 88, where *a* is the "windbore," or "snore," *b* is the "door-
taining the valve or "clack" *cd* is the bucket with
e is the "working barrel," which is bored truly

cylindrical, f is the first of the "pumps" of about 1″ greater diameter than the working barrel, g is the "collar-launder" or "hogger," by which the stream of water is delivered from the top of the column of pumps; o is the door giving access to the clack in the door-piece b. The bucket d is drawn to a larger scale in fig. 89. Its valve or clack cannot be seen in the sketch, but it is somewhat like fig. 90, which represents the clack b, fig. 88.

Fig. 89. — BUCKET-PRONG AND BUCKET. a,a, Prong; b, cottar; c,c, half moon; d, hoop of iron; e, bucket leather.

133. The Hogger, fig. 91, is sometimes substituted for the "collar-launder," shown at g, fig. 88. This is removed from time to time as the sinking progresses, another length is added to the column of pumps, and the hogger replaced. The bottom end of the pump rod is connected to the bucket-sword by means of the clasp and prongs shown in fig. 92, A, where the clasp is over the joint; B, where it

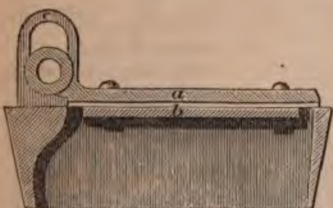

Fig. 90.—CLACK AND CLACK SEATING. a, Valve or clack; b, seating; c, guide.

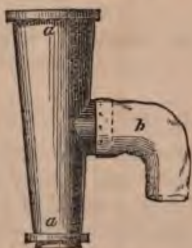

Fig. 91.—a,a, Hogger of cast-iron; b, canvas delivery tube.

is removed and the joint broken. A and B represents slightly different forms. The whole arrangement is

known as the "bottom rod" and "bucket sword." The windbore is sometimes hung from surface by means of two bars of iron called "ground spears," the bottom ends of which are shown in fig. 93 at *a*.

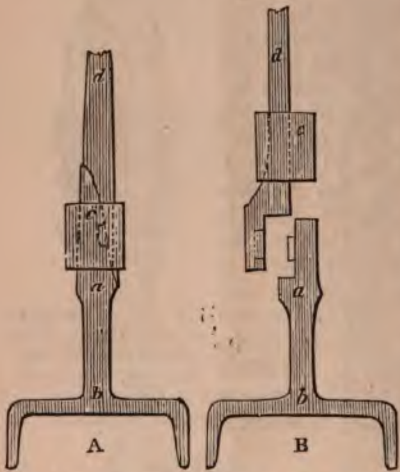

Fig. 92. — Bottom Rod-clasp and Prongs.

Fig. 93. — Sinking Windbore. *a, a,* Ground spears; *b,* windbore; *c,* wings; *d,* snore holes.

The different lengths of pipe, commonly spoken of as "pumps," are usually about 9 ft. in length, with a few "matching-pieces" of 3 or 6 ft. for convenience of fixing. They are made with simple "flanged" joints, as at *a a*, or "spigot and faucet" joints *b*, fig. 94, and bolted together through the flanges by six bolts or "flange-pins." They are cast from $\frac{1}{2}''$ to $1\frac{1}{8}''$ thick, according to size or intended height of lift, with projecting ribs and brackets for strength as shown. Fig. 94, A is an ordinary "pump," B is a "door-piece."

134. The Valves or clacks are made of iron, brass, or gun-metal, covered with stout leather or india-rubber. The hinges work in guides, as shown in fig. 90 at *c*, so that the whole valve has liberty to rise a few inches, thus giving a large water space at the commencement of the stroke. Many different forms have been devised with the object of lessening the shock in large and high lifts. One of the best, known as "Teague's clack," is shown in fig. 95 in section. For convenience of access the valve-seats are fixed in "door-pieces," as shown in fig. 88 at *o*, and in fig. 94, B.

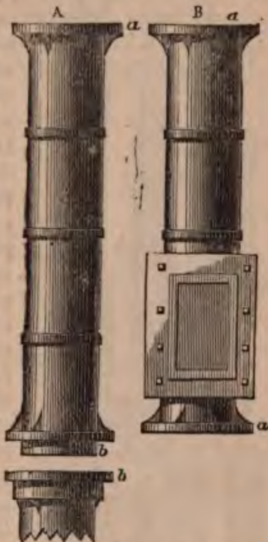

Fig. 94.—Pump and Door-piece.

135. Plunger Set.—The set already described is well adapted for use in a pit which is in process of sinking, as additional pumps may be added at the top from time to time without inconvenience or delay. If, however, the depth is more than 30 or 40 fathoms the water is usually raised in two or more distinct lifts, the drawing lift delivering its water from the hogger into a cistern A,

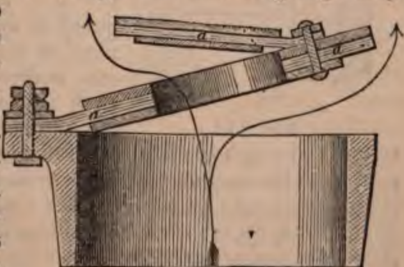

Fig. 95.—Teague's Clack. *a*, *a*, *a*, Leather valve.

fig. 96, from which it is forced to the surface by the plunger or ram *a*. By the ascent of the plunger "pole" *a* in the "case" *b*, the water which fills the cistern A is made to rise through the wind-bore *h* and clack *c* into the H-piece H. When the pole descends the clack *c* closes, the water raises the clack *e*, and passes upwards into the pumps above. As the pole again rises the clack *e* is closed, *c* opens, and a fresh portion of water passes into the H-piece. The cistern is kept full by the delivery of water from the top of the drawing lift by the collar-launder *r*, and also, in many cases, by the water from the upper portion of the mine, which is led into it instead of being allowed to fall to the bottom of the mine; *f* is the top pump of the drawing lift, and *f'* the bottom pump of the plunger lift. The plunger pole *a* works in the case *b* through a stuffing box at *i*. The mode of attaching the plunger pole *a'* and the bucket-rod *k* to the main rod *ll* by means of the "glands" *m m* and the "set-offs" *n n* is clear from the figure. The stuffing box and gland are drawn to a larger scale in fig. 97. In fig. 98 the whole of the H-piece with its two clacks is shown clearly.

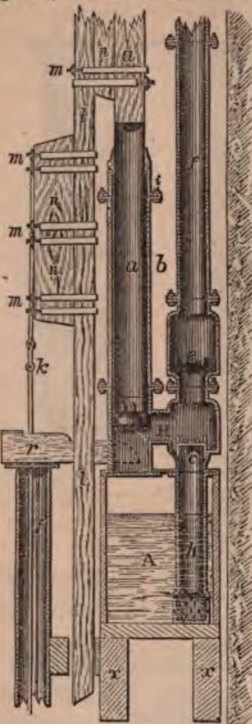

Fig. 96.

136. Ring Cribs.—The water coming into the shaft *above the plunger* cistern or "standing-set" is prevented

from falling to the bottom of the shaft by "ring cribs" communicating with the cistern. These are cribs containing a gutter hollowed out as shown in fig. 99 at *a*, the shaft being cut back just above. The water gathers in the cistern *b*, from whence it is conducted to the cistern A of the plunger set, fig. 96.

Fig. 97.—STUFFING BOX AND GLAND FOR PLUNGER POLE. A,A, Plunger pole; *a*, *a*, its metallic surface; *i*,*i*, stuffing box; *c*,*c*, gland; *d*,*d*, space for hemp packing; *e*,*e*, pole case.

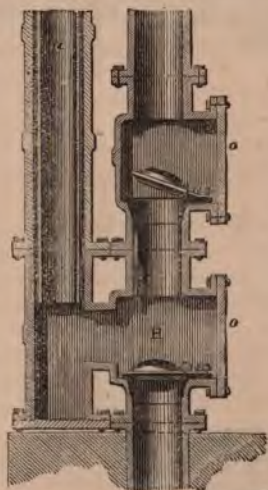

Fig. 98.—H-piece, door-piece, etc.

137. Corrosive Waters.—Sometimes the water to be raised is of a highly corrosive nature, especially where the coal or shale is "brassy." In such cases it is good economy to make the valve-seats, working-barrel, and other important parts, of gun-metal, and to line the pumps with thin staves of oak or other hard wood.

138. Fixing the Pumps.—These are fastened together

with bolts and nuts, and it is customary in some districts to place between the flanges rings of thin iron bound round with coarse flannel. This, when tightly screwed up, makes the joints air-tight, while it does not interfere with their ready separation in case of need. A better plan is to have the flanges faced in a lathe, when a thin ring of tarred canvas or india-rubber will suffice to make the joints tight.

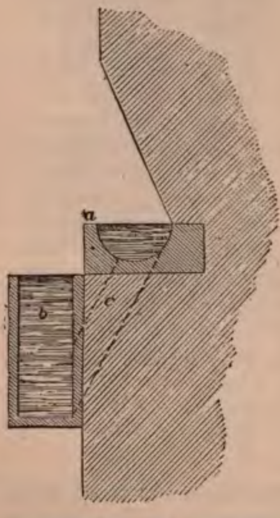

Fig. 99.—Ring Crib.

Fig. 100.

139. Main Rod or Spear.—This is partly shown at *l l*, fig. 96. In deep mines it is made of the longest and straightest balks of Norway or American pine. The *secondary rods* or spears are attached by "set offs," as

shown at $n\,n$ in the same figure. The upper end is attached to the outer end of the engine "beam" or "bob" by wrought-iron straps, secured by bolts *b* and cottars *c*, as shown in fig. 100. At intervals down the shaft catch-pieces *c c* are secured, and bearers fixed across *d d*, in order to take up the weight of the rods in case of a breakage, to prevent the whole mass of many tons weight from falling to the bottom of the shaft. They also prevent the engine from making too long a stroke, or going too far out, and so breaking off the cylinder cover.

The water is raised in the lower or drawing lift by the up or "in-door" stroke of the engine, but the remaining, or plunger lifts, are worked by the down or "out-door" stroke; the weight of the rods forcing the water up the column of pumps.

This excellent mode of attaching the various "lifts" to one main rod is not always adopted. In some districts each set has its own main rod passing up through the shaft. Comparing this method with that just described in detail, Mr. Smyth says: "When tested by the work done for a given sum of money it contrasts remarkably with the rattle and concussion, the heavy cross-heads, and the greater complication of rods that are often noticeable in other mining regions, even though the excellent invention of the plunger may have been adopted." *

140. Balance Bobs.—When the mine is deep the weight of the rods is more than sufficient to overcome the weight of the water lifted at each stroke, and the surplus is counterbalanced either by hydraulic arrangements or weights placed at the end of a lever. A very convenient mode of effecting this is by the use of "balance-bobs," placed either at surface or in chambers excavated by the side of the shaft underground. Thus, at Davey's engine at the Consolidated Copper Mines in Gwennap, Cornwall, the main rod was one-third of a mile long, and weighed 95 tons. The other rods weighed 40 tons, together 135 tons. 39 tons were required to balance the column of

* *Coal and Coal Mining*, page 183.

water in the pumps, and the remaining 96 tons were balanced—party by counter-weights, partly by special hydraulic machinery. One of these balance-bobs is shown at fig. 101.

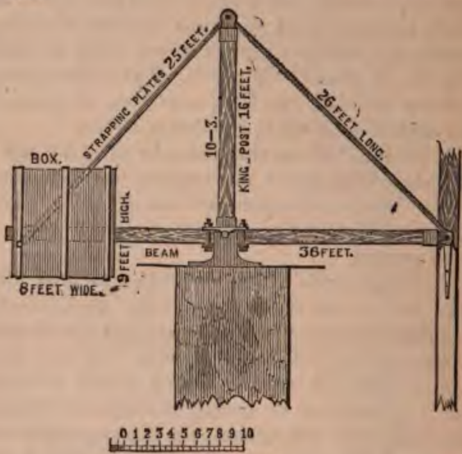

Fig. 101.

141. Crab or Capstan.—For lowering or raising the heavy portion of "pit work," as these pumping sets are called, a powerful crab or capstan is fixed just outside the engine-house in most instances. This is sometimes worked by a large number of men, but more usually by steam power.

142. Engines for Pumping.—Many different forms of engines are used for giving motion to the pumps, but the more important and permanent forms are comprised under the two heads of water-wheels and steam engines, although turbines and water-pressure engines are used in some districts.

143. Water-wheels.—For falls of water from 20 ft. up to 50 ft., the large proportion of useful effect and the *simple construction* of the overshot water-wheel are suffi-

cient to account for its almost universal adoption. To apply an overshot wheel for pumping purposes little more is necessary than the attachment of a crank and connecting rod to one end of the axle. The other end of the connecting rod, which may be short or long, of one or many links, is attached to the king-post of a balance-bob, and a reciprocal motion is at once obtained through the revolution of the crank. Sometimes the power is transmitted from the wheels to the pump rods by means of a wire rope, when a second balance-bob is placed on the opposite side of the wheel to take up the slack and keep the rope tight. Fig. 102 shows this arrangement.

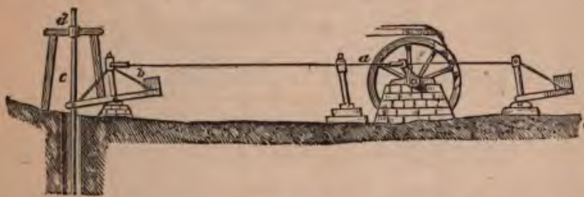

Fig. 102.—Pumping by means of a Water-wheel and Wire Rope.

In order to get the largest proportion of work out of a given fall, the wheel is frequently made several feet higher than the total fall. The water is then brought upon the shoulder of the wheel as shown in fig. 103; the launder *a* having a little fall given to it, so that the water may reach the wheel with a little more velocity than that of the circumference of the wheel itself. The wheel works more smoothly when dealt with in this manner than in any other. The water should reach the wheel at the point *b*, which is about 30° from the top of the wheel. The axle works upon brasses fitted into plummer blocks, which are mounted upon piers or "loadings" of masonry. In all water-wheels the water should be brought on to the wheels in a thin sheet of somewhat less width than the breast of the wheel itself; the buckets should be large enough to

receive all the water without any overflow at the sides, and so curved as to hold it all until nearly at the lowest point, and then to discharge it all at once before that part of the wheel begins to rise. Fall of water may also be utilised by means of "breast wheels," "Poncelet wheels," "undershot wheels," "turbines," and "water-pressure engines," but the space at our disposal will not allow of their description here.

Fig. 103.—*a*, Launder bringing water; *b*, buckets; *c*, shrouding; *d*, arms.

144. Steam Engines.—It is evident that any form of steam engine may be so arranged as to give an alternating motion to the pump rods. The forms most generally used are the Cornish Pumping Engine, the Bull Engine, the Lever and Crank Engine, and the Direct-acting Pumping Engine.

145. The Cornish Single-acting Engine, in combination with the Cornish tubular boiler and arrangement of flues, has proved itself superior to all its competitors for raising large quantities of water from great depths. This engine is shown in fig. 104, but we cannot afford space to describe it here.* A fine pair of engines of this type were erected by Messrs. Harvey & Co. of Hayle, in Cornwall,

* A description of this engine will be found at pages 98 to 102 of the author's treatise on *Metal Mining* published in this series of text-books.

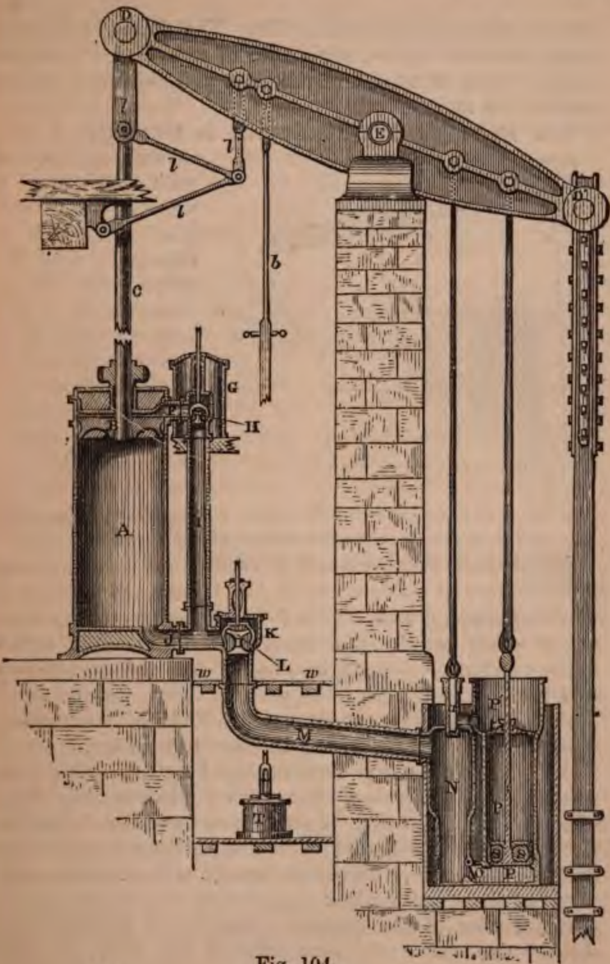

Fig. 104.

for the Tyne collieries in 1869. The diameter of each cylinder is 100 inches, the length of stroke 11 ft., weight of main beam 40 tons, and the total weight of each engine nearly 200 tons.

146. Barclay's Patent Engine is somewhat like a Cornish engine, but with its mode of working reversed. The pump-rod is attached to the outer end of the beam, and a few feet further in is the attachment of the piston-rod. The steam is admitted beneath the piston-rod, so raising it and the pump-rod together. The inner end of the beam is fixed to a rigid support, as shown in the diagram, fig. 105. This form of engine was patented many years ago by Mr. Barclay of Kilmarnock, and is rather extensively used in some of the old Scotch pits, but it is by no means to be recommended, as the strain upon the rigid support is so great. The only advantage appears to be a little saving in cost of buildings.

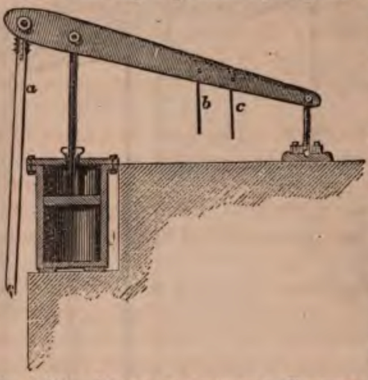

Fig. 105.—Diagram showing General Arrangement of Barclay's Pumping Engine.

147. Double-acting Condensing Engine.—This form is perhaps still the most common in the North of England, the mode of application varying much in different districts. In some collieries the old system of having a distinct main rod for each set or lift of pumps is still adopted, when some of these are worked with the up and some with the down stroke of the engine. Sometimes also auxiliary beams are employed, especially if the lifts are very numerous.

148. Direct-acting or Bull Engines.—These are placed directly over the pit, the cylinder being inverted and the piston-rod connected directly with the main rod. The cost of erection is thereby reduced, and also the first cost of the engine; but the inconvenience of covering the pit's mouth more than counterbalances these advantages.

149. Crank or Rotatory Engines.—These are double-acting engines which are usually supplied with heavy fly-wheels. They are adapted for both pumping and winding or for hauling only.

150. Horizontal Engines.—These are best adapted for hauling only, but may also be used for pumping if the speed be reduced by spur-gearing. A good form is that made by Messrs. Tangye Bros. of Birmingham, which is shown in fig. 86. A pair of somewhat different horizontal engines are shown in fig. 87.

151. Compound Engines.—In most of the engines just described the steam is worked *expansively*, *i.e.*, the steam is admitted to the cylinder at high pressure, during a part only of the stroke, and allowed to expand for the remainder of the stroke. A different mode of working steam expansively was introduced by Arthur Woolf, many years ago, in Cornwall, and after being worked some time, and somewhat modified by Sims and others, was at length abandoned. The mode adopted was to use cylinders, one much larger than the other; the small one placed sometimes above, sometimes within, the larger. Steam at high pressure was admitted to the smallest cylinder; and, after doing its work there, instead of being discharged to the condenser, was allowed to flow into the large cylinder where it expanded so as to fill it, at the same time pressing down the large piston with a certain force. The motion so produced was transmitted through the piston-rod to the main beam of the engine, and from there to the pump rods in the ordinary manner.

The greater complication of two cylinders, two pistons, and a double set of steam passages, led to the abandonment of this mode of applying steam expansively in favour

of that described in the section, but a modification of this compound engine principle is now being introduced with much success for marine and stationary engines, and with great economy of fuel.

152. Direct-acting Pumps.—Within the last few years a totally new mode of raising water from deep mines has been adopted in some districts, especially where fuel is cheap. The pumping engine is placed at the bottom of the mine, and supplied with steam through a clothed steam pipe, the boiler being above ground. The piston-rod of the engine has a piston at each end, each working in its own cylinder. That in the steam cylinder is moved backward and forward by the steam, so forcing water through the water cylinder or force-pump. From the force-pump a rising main delivers the water direct to the adit-level or the surface, as may be necessary. As water is forced by both movements of the piston, the stream is almost constant instead of being intermittent, as is the case with ordinary pumps, so that for a given delivery of water a smaller diameter of pump is sufficient. The relative areas of the two pistons are varied according to the height of the lift, for a high lift the steam cylinder is

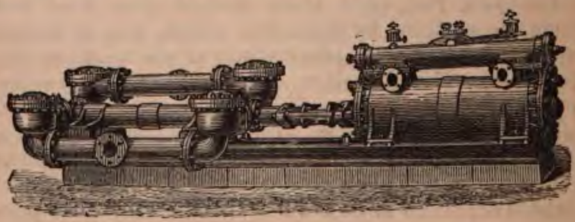

Fig. 106.

often 3 or 4 times as large as the water cylinder. Fig. 106 represents a large pump of this kind made by Messrs. Tangye Bros. of Birmingham, for Messrs. Stannies' collieries at Silverdale, Staffordshire. The steam cylinder is 32″ *diameter,* water cylinder 10½″, length of stroke 6 ft. The

engine raises 22,500 gallons per hour to a height of 540 feet.

The first cost of these "direct-acting" pumps is very low, and when they have a long stroke they work with very considerable economy of fuel, considering that the steam is used non-expansively. The expenditure for buildings is reduced to a minimum, as only the boiler needs to be "set" in masonry. In some cases the pump has been suspended in the shaft while sinking, and lowered from time to time as required.

153. The Compound Differential Engine.—A pair of compound differential pumping engines has lately been put into the Morton Pit at Clay Cross Colliery, near Chesterfield. These engines are placed at the bottom of the pit, and they force the water in a direct lift 950 ft. high. The steam is conveyed down the pit in a clothed steam pipe $7\frac{1}{2}''$ internal diameter. The loss of coal from condensation is computed at 72 lbs. per hour when the engines are idle, and 108 lbs. when working. Another lift of 1100 ft. has just been completed at the Navigation Colliery near Aberdare. The engines employed were described at the meeting of the Institution of Mechanical Engineers in London, on the 29th October 1874.

The chief drawback in collieries where fuel is of comparatively little value is, that their situation at the bottom of the mine renders them liable to be drowned out in case of a sudden accession of water beyond their capacity, or should any accident happen to them. It is therefore necessary to have the pumps in duplicate, or a serious risk is encountered.

154. Compound Direct-acting Pumps.—A convenient arrangement of a group of these pumps is that shown in fig. 107, where A A A A are the separate pumps all communicating with the suction pipe B. The delivery is through the pipe C C C. The boilers D D D are of the Cornish type; they are placed at the surface, and the steam is conveyed down the pipe E E E. By this arrangement it is possible to connect additional pumps and boilers

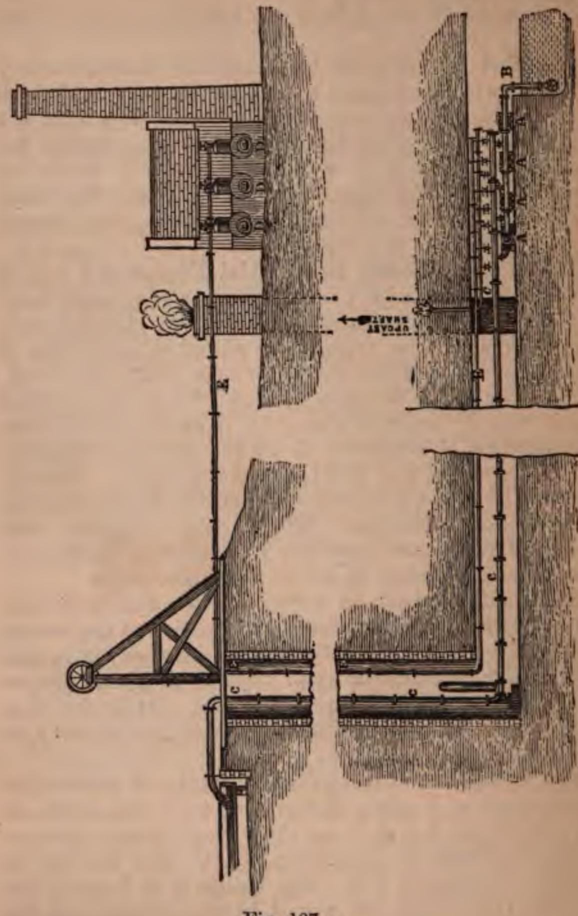

Fig. 107.

as they become necessary, and by using one pump more than is absolutely required, the risk of being drowned out is reduced to a minimum.

155. Boilers.—Among those most suitable for supplying large volumes of steam at pressures from 30 to 50 lbs. per square inch, those of the "Cornish" and "Lancashire" types are the best and most generally used in modern collieries.

156. The Cornish Boiler is illustrated in figs. 108, 109. Fig. 108 is a perspective view, fig. 109 is a section showing the mode of setting. The boiler consists of a strongly riveted cylindrical "shell," with flat ends, the angles being strengthened with "angle-irons." A cylindrical tube is riveted in the same manner to the flat ends, but nearer the bottom than the top. The fire-bars are placed

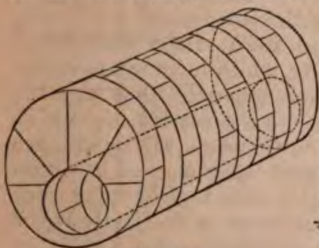

Fig. 108.

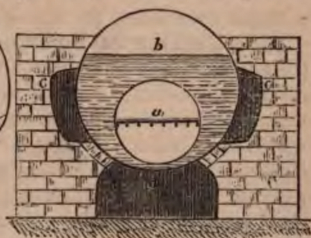

Fig. 109.

within the tubes, as shown at *a*, fig. 109, and the space around the tube is filled with water up to the water-line *b*. The boiler is supported by masonry enclosing the flues at *c c* and *d*. The flames and heated air produced at *a* pass along the central tube, return to the fire end by the side flues *c c*, and being then directed into the bottom flue *d*, pass along under the boiler to the chimney, which is placed at the farther end. The effect of this arrange- is that most of the heat of the fire is imparted to the water in the boiler before the products of combustion make their escape up the chimney. Many Cornish boilers are made from 30 to 40 ft. long and 7 or 8 ft. diameter,

with a fire tube from 3′ 6″ to 4′ 6″ diameter, and some large pumping engines require as much steam as can be supplied by three, four, or even six, of such boilers. When the length exceeds 24 ft. it is desirable to strengthen the fire-tube by rings, transverse "Galloway" tubes, or in some other manner.

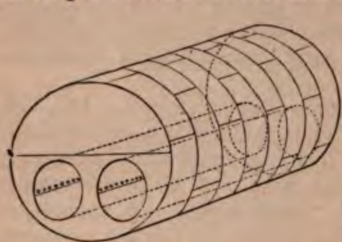

Fig. 110.

157. The Lancashire or double-flued boiler, fig. 110, is really a modified Cornish boiler in which a somewhat larger heating surface is obtained with equal water and steam space, without increasing the size of the outer shell.

158. Clothing of Boilers.—Much of the economy of the Cornish system of pumping, which is known to be the most economical, and is now generally used in large water-works, is no doubt due to the careful manner in which the boiler, steam-pipes, cylinders, valves, etc., are clothed with non-conducting material or encased in steam-packets. This is so thoroughly done that in many cases the temperature of the engine-house is uniformly below 85°, except in very hot summer weather, and the boiler-houses are but little warmer.

159. Power of Boilers.—A good ready rule for estimating the horse-power of Cornish and Lancashire boilers is to regard each square foot of fire-grate surface, or each square yard of heating surface, as equal to one horse-power. A well-proportioned boiler of either type, if properly "set" and fed with best Welsh steam coal, will evaporate from 9 to 11 lbs. of water per lb. of coal burnt, a higher result than has been attained with any other form of boiler.

160. Duty of Engines.—The engines for pumping work which give the highest useful result of "duty" are Cornish *single-acting* engines, supplied by Cornish and Lancashire

boilers. There is one instance on record of an engine of this kind * doing a duty of 145,000,000 foot-lbs., in other words, lifting one hundred and forty-five million pounds of water one foot high with the consumption of 112 lbs. of best coal. This duty was no doubt unusually high, but there are several Cornish engines now at work continuously, both in mines and water-works, whose duty is equal to 100,000,000 foot-lbs. per cwt. of *best* coal. An inferior coal is often used for the sake of economy, when the duty is of course proportionately lower. This high duty is obtained when the engines are large, do not work too rapidly, and are supplied with steam at from 40 to 50 lbs. pressure, from an abundant boiler space. Generally, it will be better to use an additional boiler for supplying steam in preference to forcing those already in use beyond their capacity. No other form of engine is known to give so high a duty as a Cornish pumping engine in perfect order.

161. Quantity of Water Raised.—This is sometimes very great. I am unable to give the exact quantities from the most extensive collieries, but one has already been mentioned from which 22,500 gallons per hour are raised. It is probable that this quantity is in some places greatly exceeded, as there is no reason to suppose that the water from extensive coal mines is less than from some Cornish mines. At Mellanear copper mine, near Hayle--a comparatively small mine—during the month of April 1873, and for many months previously, no less than 1162 gallons of water *per minute* were raised, chiefly from the bottom of the mine. In some mines the quantity raised has reached, for short periods, the enormous quantity of 3000 gallons per minute.

Austen's engine at Fowey Consols Copper Mines in Cornwall, 80″ cylinder. See Lean's *Historical Statement*, page 97.

CHAPTER XIV.

TOOLS AND BLASTING OPERATIONS.

162. The Tools used in coal mining are few in number, and generally of a simple character. They consist of picks, shovels, hammers of various kinds, wedges, borers, and a few miscellaneous tools. We can only describe the most useful, or the most common forms in the present work.

163. Picks.—These are also known as hacks, slitters, and mandrils. They vary much in form in different districts, and according to the special purposes to which they are applied. They are mostly made of iron with points or tips of steel; the handle or helve is best made of ash or hickory. The helves vary from 1 ft. 8 in. to 3 ft. 6 in. or 4 ft. long, and the weight of the pick from 2 lbs. to 8 lbs.

For sinking shafts and breaking hard rock the tool shown in fig. 111 is very useful. It has a helve about 30″ long, and the head is 6 to 8 lbs. in weight. The cost varies from 4s. 6d. to 6s., according to weight and quality.

The poll-pick, shown in fig. 112, is seldom used by coal miners in this country, but is greatly valued on the continent. When made about 5 lbs. in weight it is valuable for breaking hard rock underground, if 7 or 8 lbs., for sinking shafts in hard ground. When made lighter, say 2 or 3 lbs. only, it is a valuable tool for breaking coal in narrow seams, especially when they are steep or "rearing." The tool represented in fig. 113 is also used on the continent, and the weight is generally 5 or 6 lbs.

Fig. 114 represents a form of "hack" used in the North of England, the weight of which is usually 7 lbs.

The "holing" pick, used in North Staffordshire, is represented in fig. 115, that used in Durham in fig. 116. The curious holing tool called a rivelaine, used by the Belgian colliers, is shown in fig. 117. Another curious tool used

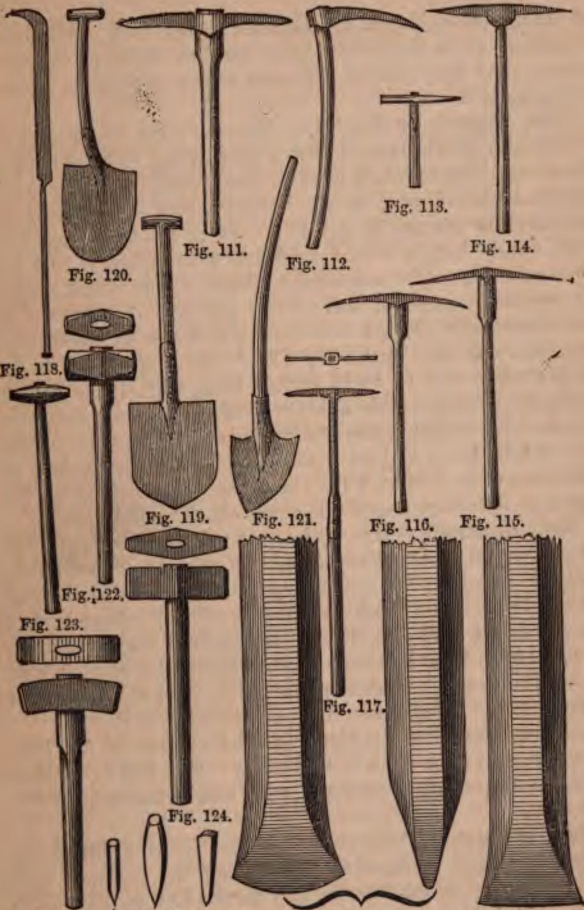

Fig. 111. Fig. 112. Fig. 113. Fig. 114.

Fig. 120. Fig. 118. Fig. 119. Fig. 121. Fig. 116. Fig. 115.

Fig. 122. Fig. 123. Fig. 117. Fig. 124.

Fig. 125. Fig. 126. Fig. 127. Fig. 128. Fig. 129. Fig. 130.

at Liege for holing is represented in fig. 118. All these "holing" tools have very long handles to allow of their being used to undercut the coal as far as possible before wedging it down.

164. Shovels or Spades.—A useful form much used in the North of England is illustrated in fig. 119. Another form, fig. 120, is much used in Staffordshire. The long-handled shovel used in the metal mines of the west of England is drawn in fig. 121. It is not much used in coal-mines, but it would be found a most useful tool for surface work or for use underground, where thick seams are worked, although some little practice is required to use it properly. In a few instances it has been introduced by miners from Cornwall. The "plate" is from 9 to 12 inches wide, and 10 to 15 inches long, slightly hollowed, and strengthened with a central rib extending half-way down. The point is usually steeled. The handle is from 3·6 to 4 ft. long, and in general curved. The weight of the plate is from 3 to 4 lbs., the cost unsteeled 5d. to 6d. per lb. Steeling, about 6d. extra on the whole plate.

165. Hammers.—The chief use of hammers in coal mining is for striking the borers in preparing shot-holes, etc., for breaking up the heavy masses of rock dislodged by the blast. A useful form for the first purpose is that shown in fig. 122. A North of England form is shown in fig. 123. The heads or panes should be steeled and the helves made of hickory or ash. The weight varies from 4 to 9 lbs., the cost from 6d. to 8d. per lb.

A good form of "sledge" is that shown in fig. 124. The weight varies from 7 to 20 lbs. Fig. 125 is another useful form. These sledges will cost from 5d. to 7d per lb.

166. Wedges.—These are much used for breaking down masses of hard rock, and wedging off the seam of coal after holing. Useful forms are shown in figs. 126, 127, 128. Wedges are often made of iron, but for hard rock they are best made of steel. Iron wedges should not *exceed 4d. to* 5d. per lb., and steel wedges about 8d.

Steel borers worn too short for use make most excellent wedges or "gads."

167. Borers.—These are often called "striking borers," "drills," "bits," and "augurs." The general form is indicated in figs. 129 and 130. The round-ended form, 129, is most suitable for boring hard rocks, the square form, fig. 130, for clift or coal. The best borers are made of steel throughout, but iron borers tipped with steel are often used and serve well enough for soft rocks. The difference of cost for a borer 5 ft. long, between steel tipped and steel throughout, will not be more than 2s. 6d., and this will be saved in boring two or three holes in hard rock, as the blow is more perfectly transmitted to the rock through steel than through iron. Borers are made of various lengths according to the depth of the hole required, but the longer rather smaller than the shorter ones of the same set. They are very readily made from round or octagon steel bars, and cost but little for making.

168. Miscellaneous Tools.—The *tamping bar* is a bar of iron, tipped with copper, or a rod of hard wood, used for ramming home a "tamping" of clay or earthy material so as to confine the gunpowder or other explosive in a bore-hole to increase its useful effect. The *pricker* was formerly much used to make a hole through the tamping, but since the invention of safety fuse it has gone very generally out of use, the tamping being now rammed around the fuse itself.

Swab-sticks are rods of wood, with the fibres of the end beaten loose, used for drawing wet mud or sludge out of a bore-hole. Sometimes a kind of syringe, known as a gun, is used with good effect for this purpose.

A hatchet is very useful in preparing timber for tender ground, and in many places the miners are very expert in its use, and also in the use of a cross-cut saw, hand saw, adze, and augur.

169. Blasting.—The process of blasting deserves careful study from every one engaged in mining operations,

whether in open works or underground. It is, of course, to be learnt by practice only, but some few general remarks will no doubt be useful. The process in outline is as follows:—A hole is first made in the rock by means of the mallet and borer. In general, one man holds the borer while it is struck or "beaten" by one, two, or three strikers, who deliver heavy blows alternately upon its head, the holder giving it about one-eighth of a turn after every blow. A little water is fed into the hole from time to time, and at intervals the "sludge" is withdrawn from the hole by means of a "swab-stick." In this way a hole is bored from 1 inch to 2 inches in diameter at the rate of from 30 to 40 inches per hour, according to the hardness of the rock.

The operation of blasting coal is very easily effected. It is rarely necessary to strike the borer with a mallet, a mere striking motion with the hand, propelling and withdrawing the borer, generally suffices. A sharp square-ended borer is the best.

170. Boring Machines.—Of late years several machines have been invented with the view of effecting the operation of boring more speedily, worked either by steam, compressed air, or water power. Some of these have proved very effective for quarry work, for driving large tunnels or sinking deep shafts, but hitherto they have not been generally able to compete with hand work underground, on the score of economy, although, where speed is an object, they may be used with advantage. Among the most ingenious of these boring machines we may mention M'Kean's, the Burleigh, and the Darlington drills, but we cannot spare space to describe their peculiarities and modes of action.

In quarry work a jumper is sometimes used for boring, especially for shallow holes, but it is rarely used by miners.

A little rotary hand borer is frequently used in boring coal and clift, the motion of the borer being given by turning a handle.

A kind of traversing boring machine has also been introduced with considerable success for "holing" the coal.

171. Charging.—The hole being bored to its proper depth, a quantity of gunpowder is placed in it, a piece of safety fuse long enough to reach the powder is placed in the hole, and it is filled up with hard clay, sand, broken brick, or other tamping material, which is driven in firmly with the tamping bar. This was formerly done with an iron bar, when the operation was very dangerous, but it is illegal now to use any other than a copper or copper-tipped bar, and accidents while tamping are of comparatively rare occurrence.

172. Firing the Charge.—The hole having been charged, the outer end of the fuse is set on fire, the workmen retire to a safe place, and, when the fire reaches the powder or other material used, it explodes with great violence. In general, the holes need not be so large nor so deep for dynamite, gun-cotton, or nitro-glycerine, as for gunpowder, and they are usually larger in open workings than underground.

The miner should so place his hole that it may encounter as nearly as possible an equal resistance in every direction, and much practice, observation, and judgment will be needed before he will be able properly to apportion the charge to the amount of work to be done. He must have a keen eye for "fissures," "joints," and "breast-heads." In some cases it will be an advantage to introduce the powder or other explosive in a cartridge form, especially in wet or loose ground.

The underclay of the seam, a portion of clift, or of the coal itself serves for excellent tamping, and the only danger to be guarded against is the ignition of fire-damp. Of course, whenever this is to be feared blasting is highly improper and should be absolutely forbidden.

173. Use of Explosives.—Accidents sometimes occur from a careless use of powder or dynamite. Powder should be kept in a tightly closed tin can holding 3 or

4 lbs., and this should be filled by a proper officer, and at an appointed place. It has been proposed to forbid the use of loose powder, and only to allow the men to use cartridges, but this plan cannot always be carried out with advantage, as it is necessary to apportion the charge for each hole according to the work to be done. Cartridges are, however, very useful for use in holes bored in a slanting position upward, and also for wet holes; but in these cases the whole of the powder should be made up into one cartridge of the size required. The miner should exercise great care, not to allow any loose powder to lie about or fall from the can, as this might become ignited and serve as a train to fire a hole before the preparations were complete.

The use of safety fuse instead of a train of loaded quills, or the use of the pricker, prevents many accidents. It is also much more economical, but none but the best should be used, or disappointment will ensue from the failure of shots. Gun-cotton has been used in a few mines, but not often of late years, as it is not found to present much advantage over powder. Dynamite is now coming largely into use, as it is greatly more powerful than powder, and may be used without inconvenience in wet places. The directions supplied by the makers are sufficient to prevent accident in almost every case if strictly complied with. In moderately cold weather it becomes frozen and will not explode. In such cases it should be thawed by steam heat, or by being kept in the breeches pocket of the miner, never by being placed over or before a fire, or in contact with metal heated other than by steam or hot water. In using dynamite, tamping is almost unnecessary.

174. Firing by Electricity.—In some large works the shots are fired at stated times, a great many holes being prepared and fired at one moment. This arrangement is well suited for quarry work, and in sinking large shafts, but is hardly suitable for general work underground.

175. Accidents in Blasting.—These occur from many causes, the chief of which are under control of the men.

By the use of copper-tipped or wooden tamping bars, the employment of safety fuse as a means of ignition, careful signalling to men employed in the neighbourhood before firing shots, and prohibition of all picking out of missed shots, nearly all such accidents may be, and in fact are, prevented in well regulated collieries.

CHAPTER XV.

VENTILATION OF WORKINGS.

176. Nature of Air.—No miner can be too much impressed with a sense of the great importance of good ventilation. The air we breathe consists mainly of two gases called by chemists "oxygen" and "nitrogen." These are mingled together in the proportion of about one part oxygen to four parts nitrogen. It is the oxygen which is really necessary for the support of life, while the office of the nitrogen is to dilute it and to increase its volume. The air being taken into the lungs in the act of breathing, the oxygen combines with spent carbon from the blood, and is thereby converted into "carbonic acid," or as it is sometimes called "carbonic anhydride." Carbonic acid is injurious when breathed, even if it is mixed with a large volume of pure air, and it should therefore be removed as fast as it is formed. When men work in the open air the carbonic acid formed is speedily dispersed, and as the supply of pure air is abundant, no ill effect follows. But it is otherwise in rooms, and especially in mines; here the air soon becomes quite unfit for use if it be not constantly renewed, hence the necessity for ventilation.

The impurities imparted to the air by breathing are much increased in mines by the constant use of candles or lamps, rendered necessary by the absence of daylight; and by the explosion of gunpowder or other agents used for blasting.

In coal mines inflammable gases called "fire-damp" are often given off in great abundance, besides which the "clift" sometimes absorbs oxygen, and so aids in rendering the air unfit to breathe.

The miner has always a good test at hand for the fitness of the air he is breathing. If his candle or lamp burns brightly and well, the air is fit to breathe; but if he has great difficulty in keeping it alight when the air is still, or if the flame becomes larger and of a pale blue colour, and flickers greatly or goes out, the air which does not properly support combustion will not support life, and some artificial means of ventilation becomes necessary, or the miner's health will give way.

This test is much more reliable than the common mode of judging by the rapidity of the current at any given point, as it may be applied in the working "ends" or "faces" themselves where the air is often stagnant, notwithstanding that there is a good current in some of the drifts.

177. Ventilation of Shafts and Trial Workings.—Ventilation may be either natural or artificial. In coal mines it is generally although not always artificial, but in trial sinkings it is often natural. In sinking shafts, unless the shaft be very deep, a simple brattice of thin wood or painted canvas dividing it from top to bottom into two will usually be found sufficient. The men working in the shaft on one side of the parting will raise the temperature somewhat, when it will be converted into an upcast, while the cool air will descend on the other side or downcast to supply its place.

178. Air-Sollars.—A natural current may often be produced in a long level by means of an "air-sollar." To form an air-sollar, the floor of the level carrying the tram road is laid about 6 inches above the actual bottom of the level, and is supported by cross-sleepers resting upon blocks of wood or stone, or the floor in the centre of the level may be excavated somewhat deeper than the sides. Planks are laid over the sleepers just mentioned,

to form a kind of deck, and the whole is rendered air tight by plastering with mud. This will divide the tunnel into two very unequal portions. Through the lower division or air-sollar, a current of cool and therefore heavy air will pass on to the "face of work."

The air heated by the breathing of the men, the heat of the lamps, etc., will pass out through the level itself, and so a constant current will be kept up. The "level" should be kept as truly level or "dead" as possible for several reasons, two of which may be mentioned here: 1st, If there be water flowing out through the level, and the fall be considerable, the rapidity of the current of water will, to some extent, check the ingoing current of air; 2nd, if the level rise rapidly, the floor of the end will soon be at a higher actual level than the "roof" of the entrance, when the heated air will actually have to *descend* in order to make its escape, although the natural tendency of heated air is always to *ascend*.

179. Cowl or Cap-head.—Should it be necessary to do more than divide the shaft, or air-sollar the levels, a "cowl," "cap-head," or "windsail," may be resorted to. This is effected as follows:—A pipe of thin metal or wood is made of about one square foot area or less, to which is fitted a revolving cap-head *a*, fig. 131. The lower end of the pipe is carried down nearly to the bottom of the shaft, and the open mouth *b* is turned towards the wind. A current of fresh air is thus forced down to the bottom of the shaft where the men are at work, and this displaces the foul air, forcing it up the shaft. In Cornwall, for temporary purposes, the writer has seen a zinc rain-water pipe so arranged with a miner's jacket extended by wires at the top for a "cap-head" or "sail." A similar arrangement may be adopted for ventilating a level, the pipe being *carried into* the end, but sharp angles in the pipe

Fig. 131.

should be avoided as much as possible. It is plain, however, that this mode of ventilation can only be adopted when the wind is blowing, but in time of calm, underground ventilation is most of all wanted. To meet this difficulty, a small fan may be placed in the upper end of the pipe, worked by hand, a water wheel, or a steam engine, and arranged either to force pure air into the workings, or still better, to draw the impure air out, leaving the pure air to find its way down the shaft.

Sometimes, by simply continuing the air pipe upwards for some feet above the shaft as a sort of chimney, and removing the cowl or turning it away from the wind, a very effective upward current is produced in calm warm weather. The cost of air pipes of thin wood 1 foot square will be from 6d. to 9d. per foot; zinc will cost three or four times as much. The pipes may be fixed by means of thin iron staples and spikes to the timbers of the level or shaft.

In many cases a jet of high pressure steam from a boiler may be discharged into the upper end of the pipe, when an outward current will be at once set up.

180. The Water Trompe.—Where there is a supply of water at surface, and a water level to carry away the waste, the water "trunk," or "trompe," may be used for ventilation with much advantage. If there be no drainage level, and the spent water would have to be pumped up again after use, it may be better to apply the power directly to produce a current of air by means of a fan or air pump, unless there be a surplus of pumping power. Figs. 132, 133 show two forms of the water trompe. In fig. 132 the water from the launder *a* falls upon the series of iron bars *b*, and down the pipe *c* into the cistern *d*. The stream of water being broken by the bars, a quantity of air is entangled and carried down with it, and this escapes at the trunk or exit pipe *e*. The water overflows the cistern *d* and is pumped up again, or passes away by an adit level. In fig. 133, the water enters the hopper by the launder *a*, passes down the pipe *c*, and falls upon

the dash-block *f*, placed in the cistern *d*, the overflow of which is at *g*. Air is drawn into the pipe *c* through the holes *b*, and makes its exit as before at *e*. By lengthening the exit pipe so as to reach into the "end" of a level, these modes may be made available for ventilating very long drifts. In all cases the exit pipe should be large,

Fig. 132.

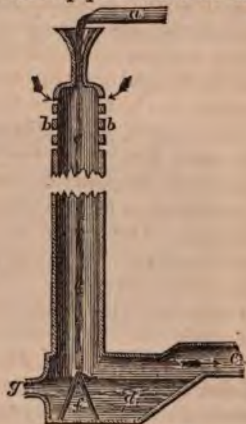

Fig. 133.

as it is quantity rather than a rapid current which is wanted, and sharp angles should be avoided as much as possible, since the air current receives a serious check at every sudden change of direction.

181. Natural Ventilation.—In working "rearing" seams such as those in the neighbourhood of Nettlebridge, to a moderate depth, the difference of level of the "braces" of the different shafts, due to the irregularities of the surface, is often sufficient to determine the direction of the current of air, and to produce a good natural ventilation, although it is sometimes necessary to use air partings or stop doors to aid this. Thus, if in a mine, situated as in fig. 134, there be two shafts, *a b*, the current will be in the direction of the arrows

when the surface temperature is warmer than that of the bottom of the mine, and it will be reversed when the surface temperature is lower. Whenever the surface temperature is the same as that of the bottom of the mine, the ventilation will be likely to suffer; but this state of things will not last many hours at any one time, since the temperature of the bottom of the mine will be constant, that of the surface rapidly variable at

Fig. 134.

different times of the day. It may be necessary to place regulating doors at *b b* and *c c*, *b b* being shut when *c c* are opened, and *vice versâ*. At *d* the current will be divided as shown. The level at *e* will be very badly ventilated unless a current of air can be sent along it by means of an air-sollar, or in some similar manner. Sometimes a chimney is built over one shaft to increase the natural inequality of level, and to assist in the determination of the current. This should be of large area, as if small, a sufficient quantity of air will not pass.

In very deep mines the difference to be obtained by means of a high chimney is very slight as compared with the whole depth of the shaft, but the naturally high bottom temperature of such mines greatly assists their ventilation by means of natural currents.

182. Furnace Ventilation.—The most general mode of ventilating collieries of any extent is to produce a

circulation of air by means of a furnace. The best mode of carrying this into effect is to build one or more furnaces in furnace drifts communicating with the upcast shaft, the object being to obtain as much difference of temperature as possible between the air in the upcast and downcast shafts, say from 60 to 80 degrees. Figs. 135 and 136 show a common construction in end elevation and longitudinal section.

Fig. 135.


Fig. 136.

When the air is foul, the furnace is sometimes fed by a stream brought direct from the downcast, while the foul air passes into the upcast at such a height as to be free from danger of firing.

Some of these furnaces consume as much as 6 tons of small coal in 24 hours, and pass 180,000 cubic feet of air per minute.

The situation of the upcast and downcast shafts is well shown in figs. 75 and 78, as well as the mode of coursing the air, adopted in pillar and stall work. The iron-work of the upcast shaft should be kept well painted, or it will be liable to serious corrosion from the heated gases.

183. Air-Pumps.—These are more largely used in some continental mines than in England, but one devised by M. Struve is largely employed in South Wales. The cost is about £200 per 10,000 cubic feet per minute (theoretical), but a large deduction must be made from the calculated quantity on account of leakage and friction.

Another form of air-pump (Nixon's) is in use at the Navigation Pit near Aberdare. One of these is calculated to pass 166,000 cubic feet of air per minute. Other useful forms of air-pumps have been devised by M. M. Brisco, Mahaux, and Scohy, but these are chiefly in use on the Continent.

184. Fans.—The use of fans for ventilation is very ancient, certainly more than three centuries; but as formerly made, the loss from leakage was very great in proportion to the power developed. More recently they have been much improved, and have come largely into use in many English collieries, especially the form designed by M. Guibal. Some of these are as much as 30 feet diameter, and with vanes 10 feet wide. Some of the greatest improvements consist in a more careful closing in of the fans, and in providing a variable outlet for the air current.

Fig 137.—Lemielle's Ventilator.

The ventilator of M. Lemielle, fig. 137, is a kind of fan which has been found very effective at home and abroad. A A is a cylinder of wood or sheet iron, B B a *revolving* drum, C C C are shutters of sheet iron which

are actuated by the iron rods *d d*. These are made to act by means of a cord working over the central axis of the drum *f* and the centre of the cylinder, I is the inlet and O the outlet.

Other kinds of fan have been devised by Messrs. Fabry, Waddell, and Lambert, but we cannot further refer to them. Generally speaking, it should be borne in mind that the best ventilators are those which move a great volume of air at a low velocity.

185. Steam Jets.—Many attempts have been made to ventilate collieries by means of jets of high-pressure steam, and some of these have been very successful except in point of economy. For temporary purposes, or in case of accident, they will be found very efficient and convenient; but for the permanent ventilation of a large colliery, a furnace, or even a fan or air-pump, will be much cheaper.

186. Coursing the Air.—In an elementary work of this kind it would be out of place to treat in detail so advanced a subject as that of the proper mode of directing the air currents in large underground works. A few general remarks must suffice:—

1. The courses from the downcast should not be too long. In general, it will be better to shorten the courses by splitting the air as it enters the mine from the downcast. Such air courses should be "balanced" or equalised as much as possible.

Fig. 138.—Air-crossing.

2. When it is necessary to carry one current of air over or beneath another, air crossings should be very strongly constructed, so that in case of accident in one part of a mine the whole system may not be destroyed. Fig. 138

is an example of such a crossing. Such crossings sometimes merely consist of bratticing, but this should only be used for temporary purposes.

3. Where independent air courses cannot be secured, the distance between the upcast and downcast should, if possible, be considerable, so that in case of explosion there may be a natural current of fresh air set up to which the men can make their escape.

4. An upcast pit on the rise of a seam will be in general preferable to one on the dip of a seam, unless the surface level is much depressed at that point.

187. Air Stoppings and Regulators.—As the working of the mine is extended, it becomes from time to time necessary to vary the direction of the courses. This is done by means of doors, when the passages have to be used, and stoppings when they are no longer required. Sometimes also it is necessary to moderate the current in certain directions, when regulators are put in.

188. Volumes of Air Currents.—These are sometimes very great, in some cases as much as 300,000 cubic feet per minute from one upcast, with a velocity of 2000 feet per minute or nearly 24 miles an hour. This velocity would be at least 10 times too fast for an ordinary drift, or, in other words, with such a velocity at the upcast, the area of the drifts ventilated may be 10 times that of the upcast. Of course the velocity in narrow parts will be greatly more, so that it must not be assumed that the ventilation is good because the current is rapid in such situations. As the volume of air required is so great, it is not possible to ventilate underground workings effectually by means of narrow boreholes from surface, a method which has been proposed by several writers.

189. Anemometer.—The quantity of air passing through a drift may be ascertained by means of the instrument known as the anemometer. This is a lightly made metallic fan which revolves when it is held in the current. The number of revolutions is indicated by wheel-work and a series of small dials. To get accurate results it is

necessary to hold this instrument at top, bottom, sides, and centre of drift, and to take the mean as the actual velocity. This, multiplied by the area of the drift, gives the quantity of air passing. Approximate results may be obtained by observing the time occupied by a puff of smoke or a patch of wool in traversing a measured distance, but this always gives too high results, as the air moves faster in the centre of the drifts than elsewhere.

The "manometer" should also be used in order to determine the different densities of the air currents in different places, by which means the existence and situation of unusual obstructions is often indicated.

190. Barometer.—This should be found in the manager's office of every fiery colliery, as it has been observed that a large proportion of explosions occur during or immediately after a sudden or considerable fall of the barometer.

191 Heat of Deep Mines.—The ventilation of deep mines is somewhat assisted by the high temperature which favours the escape of the foul gas from the upcast. The rate of increase of temperature in deep mines varies much in different localities. In some places it has been found as much as 1° F. for each 45 feet in depth, in others little more than half this rate. After about the first 10 fathoms the variations of surface temperature have no effect on that of the mine below, which, in the absence of chemical changes or of hot springs, is always almost exactly the same. One exception, however, must be noted. In deep workings, when they are are first opened, the temperature is often much higher than in the same situations after several months working. Thus, at the Clifford Amalgamated Copper Mines, in Gwennap, the air in the 220 fathom level was 100° F. in 1863; but in July, 1864, it had sunk to 83°. In the 230 fathom level then just opened, the temperature at the same date was 104° F.

At the Duckinfield Colliery, in Durham, the temperature was found to increase from a depth of 20 feet down to 358½ fathoms, at an average rate of 1° F. for each 88 feet in depth. At the Rose Bridge Colliery, near Wigan,

from a depth of 80½ fathoms to 403 fathoms, the average increase was at the rate of 1° in each 67 feet. This latter is one of the deepest mines yet worked.

Perhaps the greatest depth yet attained is at *Viviers Reunis*, near Gilly, in Belgium, where the shaft itself reaches a depth of 3411 feet, or nearly 570 fathoms, and the bottom of a *trial-staple* was found by Mr. W. W. Smyth, in 1871, to be 3489 feet, or 581½ fathoms.

CHAPTER XVI.

LIGHTING OF WORKINGS.

192. Candles.—In the anthracite mines of South Wales, and in some of the collieries of Somerset and the North of England where outbursts of inflammable gas are unknown, the usual mode of lighting the miner at his work is by means of tallow candles, of about 20 to 30 to the pound. These candles are held in place by means of a spike and holder, or else by a lump of clay. The candle itself is a sure but dangerous indicator of the presence of fire-damp, as, when this is present, it becomes elongated and of a blue colour, often with a kind of brownish-grey tip. It is sometimes used to test the air, but this should never be done where an explosion would be dangerous.

193. Open Lamps.—These are more used in Saxony and Belgium than with us, but they are sometimes met with in England and Wales. They are made to burn colza, rape, or paraffine oil, and to supply a very cheap light, but are often accompanied by an unpleasant smell. The cost varies from ½d. to 1d. for each shift of eight hours.

194. Coal Gas.—This is largely used in some of the non-fiery mines of the North of England, especially in lighting the shafts and rolley-ways. It is very economical considering the excellence of the light given. In some cases blowers of gas from the coal have been utilised for *this purpose;* but the use of naked lights is improper in

seams where blowers are given off except in the downcast shaft. Sometimes the gas is made at surface, stored in a gasometer, and sent down by means of a fan-blower or a water trompe. A current having a force equal to a pressure of 10 or 12 inches of water is found sufficient to carry the gas down to a depth of 150 to 200 fathoms, and to maintain sufficient pressure at the burners. In mines where furnaces are used for ventilation the retorts are sometimes placed over the furnace, and the gas is purified and stored underground.

In the United States a kind of gas is produced for mining and other purposes by forcing common air through benzoline. This gas is slightly heavier than air, so that no difficulty is experienced in conveying it underground, as is sometimes the case with coal gas. The first cost of the apparatus is much less than that necessary for the production of coal gas, the complete arrangement for fifty lights only costing from £60 to £100. The forcing apparatus is a kind of clockwork, which is wound up night and morning by one man in less than an hour, and the light is said to be quite equal to coal gas, or even superior to it. The cost for each light is about ½d. per hour. This would be too costly a light to supply to each pair of men; but not too costly for the lighting of shafts and main roads, or levels, or other fixed positions, where a constant light is needed. This mode of gas lighting was to be seen in the International Exhibition at South Kensington (July 1874). It seems to be admirably adapted for mining purposes.

195. Safety Lamps.—These are the most generally used sources of light in coal mines, and the only kind that should be employed in any situation where blowers of gas are to be feared. They are of many kinds, but all depend upon the principle first made known by Sir Humphrey Davy in 1815-16. By a series of experiments, Sir Humphrey found that except under pressure flame cannot pass through a wire gauze of about 800 meshes per square inch, so that a flame may be safely burnt in an explosive

atmosphere if enclosed in a cylinder of such gauze. It has, however, been shown that when the explosive gas moves at a greater rate than 3 or 4 feet per second, the flame will sometimes pass through the gauze, when such lamps become dangerous. Several modern improvements have been devised with a view to rendering the lamps truly safe, even under such conditions as these. The ordinary Davy lamp consists simply of a cylinder of wire gauze fixed to a brass ring which screws on to the lamp proper. The upper portion is double, for greater safety, and is covered by a metal top. A bent wire passes up through the oil vessel, so that the lamps may be trimmed from without. Sometimes a shade and reflector is added made of tin or horn.

Fig. 139.—Clanny's Lamp.

Clanny's lamp differs from the Davy in being composed of glass in its lower part and the upper part of gauze. As improved by modern makers it is preferable to the Davy, because it gives a better light. An improved Clanny is shown in fig. 139. Dr. Clanny seems to have invented his lamp about two months before Davy's was introduced, but not before Davy's experiments. Stephenson's lamp, or the "Geordy," has both a glass and a wire guaze cylinder, and is covered with a perforated cap of copper. Other lamps have been invented or improved by C. Muessler, Botz, and Eloin.

It is imperatively necessary that the use of safety-lamps should be accompanied by stringent regulations, indeed it is better that they should be filled and fastened *by a responsible* officer, who should examine their condition *every time they* are given out for use.

EXAMINATION QUESTIONS.

Cheifly selected from the questions set at the May Examinations of the Science and Art Department. The numbers within brackets refer to the paragraphs in which the material for answering the respective questions will be found.

1. Describe the usual modes of occurrence of coal seams in the earth [5].

2. Give a sketch section of some coal-field or coal-basin known to you [8].

3. What is an "underclay?" [12].

4. Give the name and composition of the various rocks and minerals found in the coal-seams and ironstones of the coal-measures [15].

5. Describe the way in which steam power may conveniently be applied to working the apparatus for deep boring, as of artesian wells [33].

6. Describe the apparatus commonly used for deep boring, and the conditions under which they may come into use for auxiliary operations in mines [26, 33].

7. Describe the cutting tools employed in rope-boring, and compare the results of this method with those of boring with rods [31, 36].

8. Describe the various methods of working the rod or rope for deep borings [33, 34, 36, 37].

9. Describe generally the chief improvements in the system of boring for exploration or for artesian wells [37-39].

10. State the depth of the deepest bore-holes known to you [35-42].

11. Describe the various kinds of tubing that have been applied to artesian wells, with the modes of jointing and of withdrawing the tubes [32].

12. Describe the mode of boring against old wastes [91].

13. State what you know of the cost of deep borings by various systems [42].

14. Give sketch sections of ordinary faults, "reversed" faults, and "trough" faults [45, 46, etc.].

15. What do you understand by the terms "nip," "balk," "swelly," and "horse-back?" [50, etc.]

16. What is a dyke, and what is its general effect upon a seam of coal in its vicinity? [52, etc.]

17. Give evidence of stratified minerals being of different thickness and quality on opposite sides of faults or slip-dykes [50, etc.].

18. State the general phenomena of "faults," "throws," and "hitches," in coal seams [45. etc.].

19. Make a hand sketch on scale of not less than one inch to six feet of the plan and section of timbering for securing the sides of a shaft [59, etc.].

20. State in detail the method and the average expense of securing, with either brick or timber, 50 fathoms depth of a shaft of given dimensions [57-62].

21. Describe a shaft tubbing of cast-iron, and the process of fixing it in its place, and approximate cost [63-65].

22. What are the approximate height and thickness of segments of cast-iron "tubbing" to be fixed in a 15 foot pit to withstand a given height of pressure? [60-64].

23. Describe, with a sketch, the mode of pile-sinking, "spilling," through running ground [60].

24. Describe the process of putting in plank brattice and bunton brattice [68].

25. State the qualities, dimensions, and prices, of the varieties of timber most suitable for use in mines [69].

26. Give examples of the more difficult kinds of ground to drive or sink through, stating the prices of such operations under ordinary circumstances [60-65].

27. Describe the preparatory operations in the commencement of the sinking of a shaft [57].

28. Describe in detail the most approved mode of sinking a shaft through surface quicksand of, say, 60 feet deep [60].

29. In the sinking of a shaft below a given level, how should the men in the deeper sinking be protected against the fall of stones, etc., from above? [81].

30. Show how to construct a "pent-house" for the safety of the men occupied in sinking a shaft while work is going on above their heads [81].

31. How would you construct a bratticing in sinking a deep trial pit? State what would be the cost of your arrangement [68].

32. In what way may winch or windlass handles best be fixed, of what length, and at what height from the ground? [72].

33. Calculate the amount of water or rock which may be drawn in 8 hours by two men at a tackle or windlass, from 10 fathoms deep [79].

34. Show the exact construction of a windlass or "jack-roll," as used in a given district, with dimensions [72].

35. Show by a drawing the securest forms of knot and hook for attaching the weight or kibble in drawing by means of a windlass [77].

36. Make a drawing, and give the dimensions of each part of a horse-whim or gin [74].

37. Make a calculation, showing the grounds on which you proceed, of the weight of mineral which may be drawn in eight hours from 100 yards deep by two horses with a whim or gin [79].

38. Give a sketch, not less than two inches in height, of the ordinary timbering of a level, and state reasons for making the cap-piece short and inclining the legs or stanchions [66].

39. State, with the help of figures, the best form to be given to the arching of levels or drifts with brick or stone under various circumstances [85-90].

40. Make sketch drawings showing the best methods of fitting the cap or cross-tree to the wall-plates, legs, or stanchions, in the timbering of a level or drift [66].

41. What is the mode and the expense per fathom of "arching," in brick or stone, a level of seven feet by five feet internal measure? [87].

42. State the dimensions of openings and pillars in various cases of post and stall work, with the reasons for the employment of such dimensions [99].

43. Give the dimensions and cost of levels and drifts, as intended for various purposes [90].

44. Give a description of "long-wall" workings, stating the distance apart of the roads, the advantages of the system, and under what system it is most applicable [102].

45. What are the chief modifications in the system of working stratified minerals by post-and-stall or bord-and-pillar? [99, 100].

46. State facts showing how the inclination or "pitching" of a seam of coal may affect the safety of its working [181-186].

47. State the relative advantages and the weight and dimensions of the different kinds of mining pick with which you may be acquainted [163].

48. State the weight and strength of the different kinds of ropes, of hemp or wire, which are commonly employed in mining [121].

49. What are the essential points in the construction of the Davy, Stephenson, and Clanny lamps, and with what velocity of the air do they become insecure? [195].

50. Illustrate with a sectional drawing and dimensions a description of a dam to keep back at least 30 fathoms of water [95].

51. Compare the economy of the tramming or conveying of mineral a distance of 100 fathoms, (1) in barrows, (2) in tram-waggons or tubs on rails [109].

52. State the particulars, with form and weight of waggon, of the most economical system of underground conveyance of mineral [108].

53. Give the mode of fitting up and the cost per fathom of guides or conductors in mining shafts [115].

54. What is the construction of the "water-balance" for

winding material, and under what circumstances is it most applicable? [113].

55. State exactly the inclination or gradient (assigning reasons for it) which should be given to the main levels of collieries [106].

56. State the particulars of the best class of engines for winding or hoisting minerals in shafts [128].

57. Describe the most advantageous modes of utilising water power for mine machinery [112, 113, 143].

58. State the particulars of various kinds of rope and chain employed in mines, and their applicability under different circumstances [121].

59. State the form, weight, and best mode of laying underground rails [107].

60. Enumerate the precautions to be taken against accidents in drawing or winding shafts [119, 124].

61. State the comparative advantages of winding or hoisting minerals in kibbles or buckets, and in guided skips or cages [79, 114].

62. Make working drawings of the best kind of waggon or tub, which you may know, for underground haulage of mineral [108].

63. Draw the horizontal section and elevation, with measurements attached, of a shaft intended for pumping and hauling, with its timbering or lining, and brattices or divisions [59, 119].

64. Describe in detail the operation of boring holes for shots [169].

65. What is the form and weight of the tools employed for blasting rocks, and what the materials of each, suited to greatest efficiency and safety for the operators? [165-167].

66. Give examples of the use of wedging in breaking coal and rock, and show how far it is possible to substitute it for blasting with gunpowder [104, etc.].

67. State the modes of fixing, and the different materials of which air-boxes or air-pipes are made, and their relative advantages [179].

68. State the principles on which at different seasons of the year a circulation of the air takes place in workings [181].

69. Describe the advantages and the practical method of splitting the air in extensive mines [186].

70. Give a sketch drawing of a good form of ventilating fan or air-machine, with dimensions, and results of calculation or experiment on results [184].

71. What is the velocity of air-currents in the main workings and in exceptional parts of mines? [188].

72. Describe the most satisfactory mode of constructing "stoppings" and "crossings" for the air-ways of a colliery [186, 187].

73. What measures may be taken, without introducing machinery,

exciting a ventilating current, to improve the air in a particular district in a mine? [180-182].

74. State in detail the results that are produced in the air, in various classes of mines, by great depth [181-191].

75. Why is it not a proof of good ventilation in a mine to have a very rapid current of air in a small place? [188].

76. State the objections to the plan which has been sometimes suggested of ventilating the goafs of collieries by bore-holes from the surface [188].

77. Describe the construction of a good ventilating furnace for a moderately extensive colliery, and the reasons for various modes of supplying it with air [182].

78. What are the best varieties of safety lamp, and what precautions should be observed in their use? [195].

79. Make sketch-drawings, and explain the action of the water-blast commonly used in small mines [180].

80. What are the circumstances under which gunpowder for blasting may be put in loose or should be in cartridges? Compare the two methods [173].

81. Describe the advantages of the use of safety fuse [172, 173].

82. What are the various kinds of explosives in use for mines, and their comparative advantages? [173].

83. Enumerate rules for the safe employment in mines, of dynamite and gun-cotton [173].

84. Under what circumstances does it become desirable to use the battery or electro-magnet machine for firing charges? [174].

85. Draw a figure of, and state the materials of the different parts of the "drawing lift" or "bucket set" of a mine pump, and explain why it is desirable always to have such a lift in the bottom of a shaft [131-134].

86. Show by a sketch section the construction of a plunger-lift, with its cistern, stuffing-box, and connections [135, 136].

87. Describe the most approved method of placing the various set of pumps in a shaft of 300 fathoms in depth, for raising a moderate stream of water [131-135].

88. State the meaning of the term "duty" applied to pumping engines, and the comparative duty (with reasons for it) attained by the best Cornish engines [160].

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